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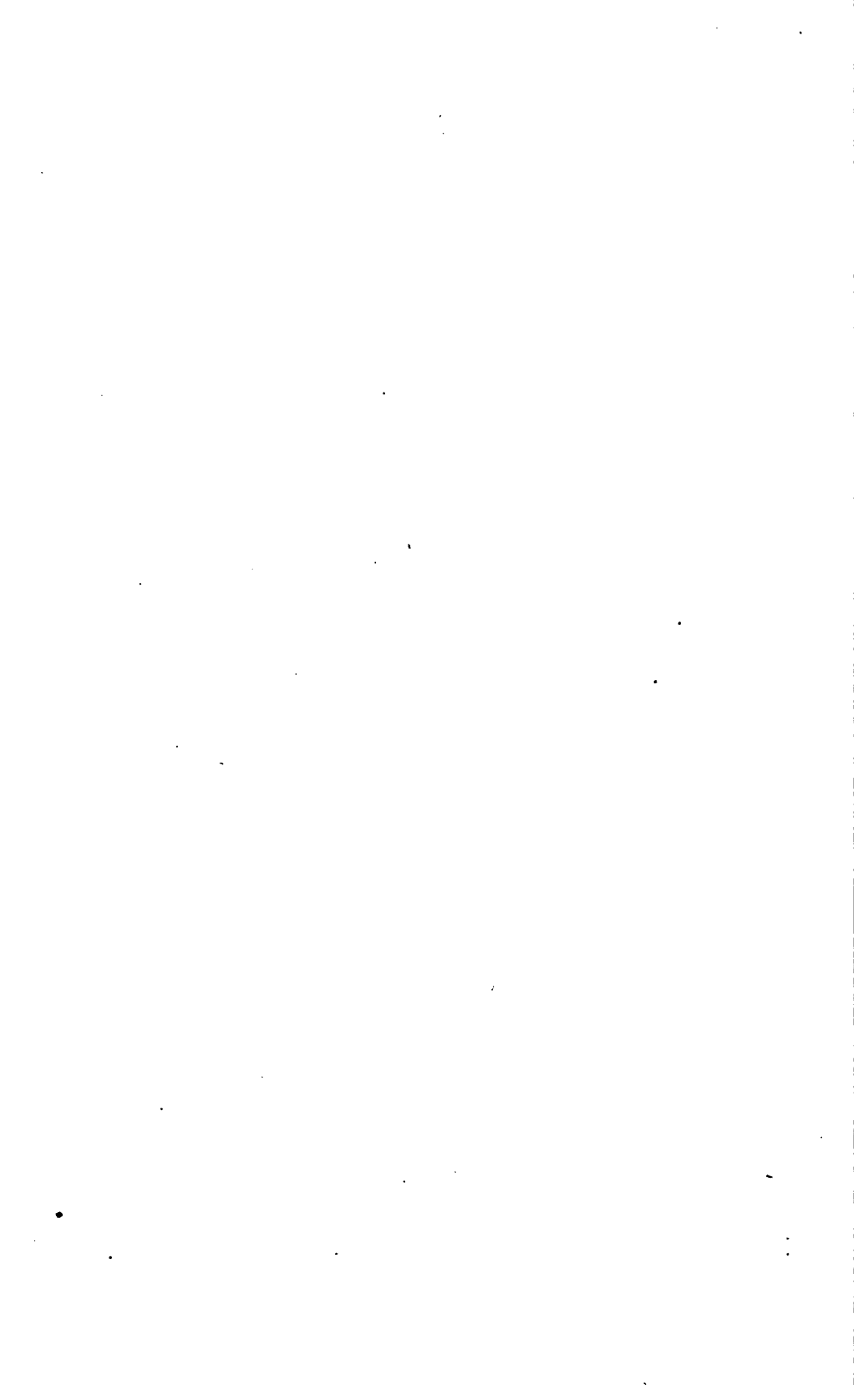
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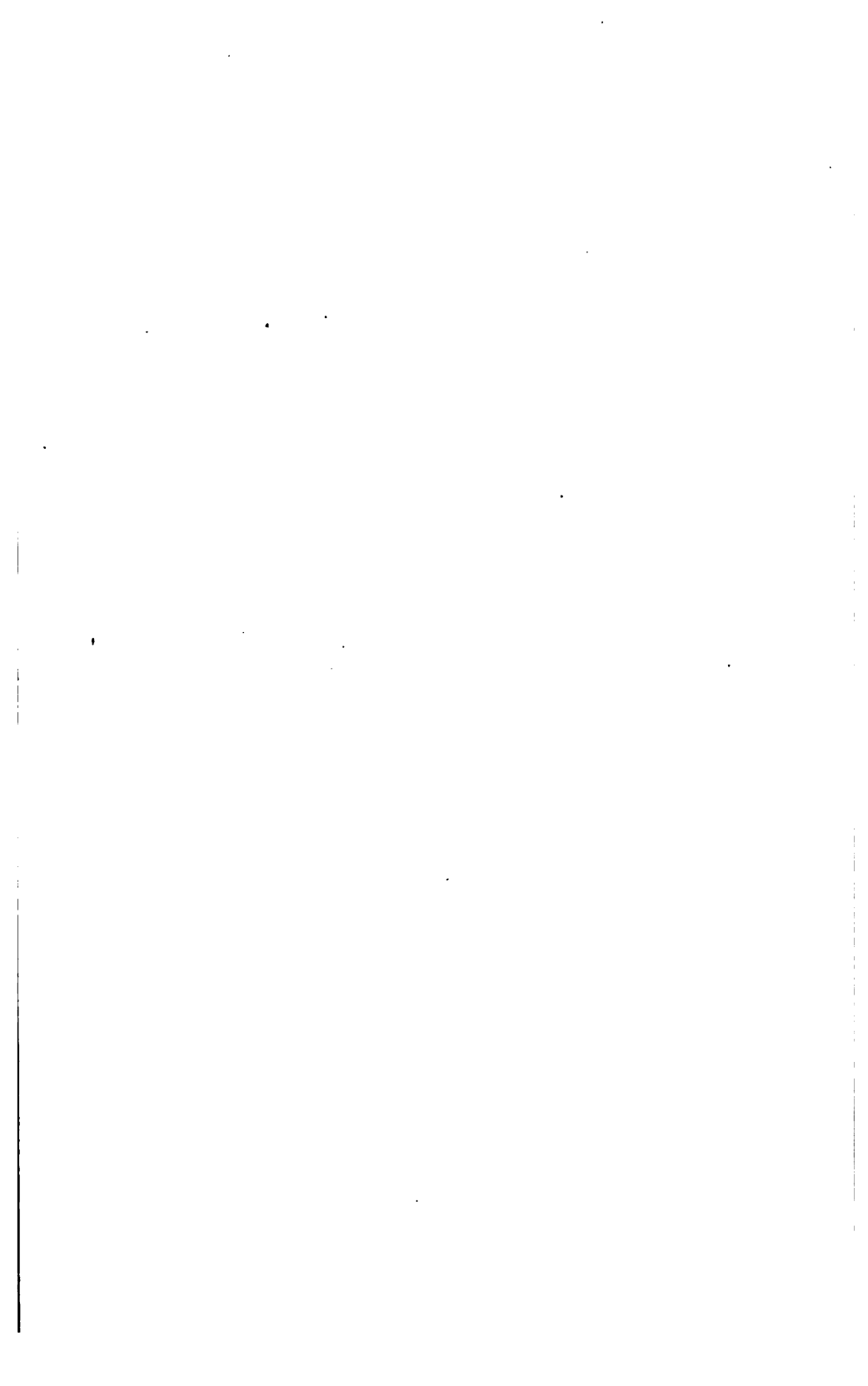
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# Bulletin of the American Institute of Mining Engineers.



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## **HARDINGE MILL RESULTS AT MIAMI COPPER CO.**

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PLANT, THE OPERATING LABOR  
COST OF FINE CRUSHING HAS  
BEEN REDUCED ABOUT ONE  
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ICAL WATER CONSUMPTION,  
LOWER MAINTENANCE AND  
OPERATING COST, AND A VERY  
LOW RATE OF DEPRECIATION."**

**—From Chile Mills vs. Hardinge Mills,  
paper presented before the Butte meeting  
of the A. I. M. E., by Mr. Robert Franke,  
of Miami, Ariz., Aug., 1913.**

**HARDINGE CONICAL MILL CO.  
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# BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.

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Subscription (including postage), \$10 per annum; to members of the Institute, public libraries, educational institutions and technical societies, \$5 per annum. Single copies (including postage), \$1 each; to members of the Institute, public libraries, etc., 30 cents each.

Entered as second class matter, October 16, 1911, at the post office at Philadelphia, Pa., under the Act of March 3, 1879.

**October Meeting of the Institute.**—Invitations have been sent to the members of the following societies through the respective Secretaries to attend the October meeting of the Institute and the Dinner which will be given on the evening of Oct. 17:

American Society for Testing Materials,  
American Iron and Steel Institute,  
American Society of Mechanical Engineers,  
American Society of Civil Engineers,  
American Institute of Electrical Engineers,  
American Foundrymen's Association.

Members of these Societies have also been invited to contribute to the discussion of the various papers to be presented at the meeting, a revised list of which appears in the notes of the Iron and Steel Committee on p. vi. Many individuals of national and international prominence have also been invited to contribute discussions of these papers, and the response to these invitations has been extremely encouraging.

**Oregon Local Section.**—At a recent conference in Portland, Ore., of the Secretary of the Institute and some of the local members, the subject of the formation of an Oregon Section was discussed. The suggestion was received with enthusiasm and, as a preliminary step in the formation of such a section, the Oregon members enlisted in a campaign to extend the membership of the Institute within the State as well as to secure papers on Oregon mining and geological subjects.

**Nominations for Officers.**—The Committee appointed by the Board of Directors to nominate officers for the Institute for the year 1914 desires that every member participate in the work by offering suggestions and proposing names for the various offices, thereby obtaining the best ticket that can be recommended.

The officers to be elected at the annual meeting in February, 1914, are:

One officer, known as Director and President.

Two officers, known as Director and Vice-President.

Five officers, known as Director.

The attention of members is called to Articles V and VII of the Constitution, and to By-Law XIII, which reads as follows:

‘The Geographical districts to be considered by the Committee on Nominations shall be as follows, until otherwise ordered by the Board.

District No. 1. New England, New York, and New Jersey, excepting New York City and district, which is provided for in the Constitution. [N. B.—New York City and district is designated District 0.]

District No. 2. Pennsylvania.

District No. 3. Ohio, Indiana, Illinois, Iowa, and Missouri.

District No. 4. Minnesota, Wisconsin, and Michigan.

District No. 5. Montana, North and South Dakota, Wyoming, Nebraska, Kansas, Washington, Oregon, Idaho, and Alaska.

District No. 6. California and Nevada.

District No. 7. Utah, Colorado, Arizona, and New Mexico.

District No. 8. Louisiana and Texas.

District No. 9. Other Southern States and District of Columbia.

District No. 10. Mexico.

District No. 11. Canada.”

An excerpt from Article VII of the Constitution reads as follows:

“In making such selections [namely, the 8 Directors to be elected], the Nominating Committee shall, so far as practicable, distribute the representation on the Board geographically, so that seven members shall be residents of the district including New York City and the territory within a radius of fifty miles of the headquarters of the Institute, and one member a resident of each of the geographical districts enumerated in the By-Laws.”

The officers of the Institute whose terms expire are as follows:

President, Charles F. Rand (not eligible for re-election).

Past President, Charles Kirchhoff.

Vice-Presidents, Karl Eilers, District 0; Waldemar Lindgren, District 1.

Directors, James Douglas, District 0; James Gayley, District 0; Albert R. Ledoux, District 0; Charles W. Merrill, District 6; and C. Snelling Robinson, District 3.

It is hoped that the members of the Institute will help the Committee to the utmost by making suggestions and proposals as requested above, which should be sent to the Chairman of the Nominating Committee, John Hays Hammond, 71 Broadway, New York, N. Y.

JOHN HAYS HAMMOND,  
*Chairman, Nominating Committee.*



## PERSONAL.

(Members are urged to send in for this column any notes of interest concerning themselves or their fellow-members.)

Members who registered at Institute headquarters during July and August:

R. H. Sweetser, Columbus, Ohio.  
 Raymond Brooks, Goldfield, Nev.  
 Edward M. Shepard, Springfield, Mo.  
 Rudolf Gahl, Clifton, Ariz.  
 Edmund von Maltitz, Pittsburg, Pa.  
 M. K. Rodgers, Seattle, Wash.  
 M. B. Cohen, Miami, Ariz.  
 A. P. Watt, Newark, N. J.  
 H. H. Stock, Urbana, Ill.  
 D. W. Brunton, Denver, Colo.  
 C. S. Robinson, Youngstown, O.

C. R. Hill, New York, N. Y.  
 H. A. Morrison, Candor, N. C.  
 Frederick J. Patchell, Washington, D. C.  
 Walter F. Pyne, New York, N. Y.  
 Harvey B. Small, Mangangué, Colombia,  
 S. A.  
 J. F. Erdlets, Jr., New York, N. Y.  
 D. H. Ladd, Houghton, Mich.  
 Roy F. Cornell, Santa Cruz, Cal.  
 W. B. Foote, Geneva, N. Y.  
 H. Sjogren, Stockholm, Sweden.

**J. L. W. Birkinbine** is manager of the Benson Mines, St. Lawrence county, N. Y.

**Francis Church Lincoln** has resigned as professor of Mining Engineering at the University of Illinois to become resident engineer for the Bolivian Development & Exploitation Co., with headquarters at La Paz, Bolivia.

**Frank C. Laurie** has been appointed General Manager for the Cia. Mexicana de Petroleo "El Aguila," S. A., in charge of the southern oil fields, with residence and headquarters in Minatitlan, Vera Cruz.

**J. E. Johnson, Jr.**, has opened an office as consulting engineer and metallurgist. He will specialize in making investigations and reports on industrial plants and processes and in the engineering and operation of blast furnace and steel plants and iron mines. He has associated himself with Sanderson & Porter, Engineers, 52 William Street, New York, N. Y.

A complimentary dinner tendered to **Oberbergat Dr. h. c. Richard Beck**, Rektor magnificus of the Königliche Bergakademie, Freiberg, Saxony, Germany, and the members of the Old Freibergers in America by Frederick G. Corning, was given at the Engineers' Club, New York, on Tuesday, September 9, 1913. Franklin Guiterman acted as Toastmaster. Dr. Beck, Dr. R. W. Raymond, Secretary Emeritus of the American Institute of Mining Engineers and President of the Old Freibergers in America, and Charles L. Bryden, the Secretary-Treasurer, responded to toasts. Besides the guest of honor, those present were: T. Waln Morgan Draper, Franklin B. Guiterman, Albert Meyer, Dr. P. J. Oettinger, Dr. R. W. Raymond, Baron Alfred von der Ropp, Dr. Gardner F. Williams, O. G. Schultz, Dr. F. A. Wilder, Dr. William B. Phillips, Dr. Arnold Hague, H. H. Knox, G. McM. Godley, Prof. Waldemar Lindgren, H. A. J. Wilkens, H. H. Webb, R. M. Payne, C. L. Bryden.

**G. B. Street**, Mining Engineer with the E. I. duPont de Nemours Powder Co., is now at duPont, Wash., investigating the various sources of heavy sulphide ores suitable for use in manufacturing sulphuric acid.

**H. A. Morrison**, formerly Mine Superintendent, Uwarra Mining Co., Candor, N. C., has accepted a position with the Globe Consolidated Mining Co., Dedrick, Trinity county, Cal.

**Dr. A. N. Winchell**, Professor of Mineralogy and Petrology in the University of Wisconsin, is spending the summer in a study of the mineral resources and geology of southwestern Oregon for the Oregon Bureau of Mines and Geology. He expects to prepare a report during the coming year.

**Prof. James F. Kemp** has received the honorary degree of Doctor of Laws from McGill University.

## ENGINEERS AVAILABLE.

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

A member, technically educated, with 20 years' practical experience as engineer, assistant superintendent, superintendent, and manager of large mines and mills on construction and operation, also experience in mine examination, is open to engagement.

Metallurgist of 18 years' experience in Mexico with large plants is open to engagement. Last position, superintendent of copper smelting works. Best line, copper and lead smelting, but also experienced in mine valuation and ore-treatment investigation work. Speaks Spanish.

A member of the Institute and graduate mining engineer with 10 years' experience in the Lake Superior copper district, also practical experience, desires position as superintendent or manager.

Member, graduate mining engineer, experienced in mine and mill work, geology and field work, one year in the hydrometallurgy of copper, is open for engagement Aug. 15.

A member, at present in the Southwest, desires a position as assistant superintendent or assistant manager with a mining company operating in Washington or Alaska. Experienced assayer and engineer.

A member, technical graduate, with nine years' mining experience as assayer, engineer, foreman, manager's assistant, and superintendent of large development and operating mining companies in the United States and Mexico, is open for engagement.

A member, technical graduate, 33 years of age, 11 years' experience as chemist, metallurgist and superintendent of lixiviation plant and in charge of construction of cyanide mill, desires position as assistant superintendent or superintendent of mining or milling company in United States or Canada.

Young man, technical graduate, two and a half years' experience in chemical laboratory, desires position as chemist.

Young man, recent graduate in mining and geology, desires position.

Fuel expert, graduate chemist, four years' experience in chemical routine and research work on fuels and chemical side of engine-room and boiler-room problems. Classification and valuation of fuels and solution of feed water troubles a specialty.

Metallurgist, experienced in the handling of carbon, alloy and tool steels, desires a position with a steel company, preferably as traveling sales metallurgist.

Graduate chemist, with seven years' experience in analytical work, including gold, silver, zinc, fuels, desires a position, preferably in the West, as chemist or foreman in a metallurgical plant.

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## POSITIONS VACANT.

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Position of laboratory assistant in metallurgy, pyrometry, and physical testing is vacant. Salary \$80 to \$100 to start. Knowledge of metallography desirable.

Opening for a mine superintendent familiar with stoping methods on narrow gold quartz veins; also for a superintendent of a 50-ton fine-grinding cyanide mill. College man under 40 preferred.

Position in sales department is open for a mining engineer with experience in mine ventilation and possessing some knowledge of fan design; one competent to lay out ventilating systems to meet various conditions.

## READY FOR DISTRIBUTION.

## EMMONS VOLUME ON ORE-DEPOSITS.

*Ore-Deposits—a continuation of the "Posepny" Volume.*

Comprising papers descriptive of ore-deposits and discussions of their origin, edited, with an introduction, by Dr. S. F. Emmons. The volume contains also a Biographical Notice of Dr. Emmons by his associate and friend, Dr. George F. Becker, and a comprehensive Bibliographical Index of the Science of Ore-Deposits, prepared by Prof. John D. Irving, of the Sheffield Scientific School of Yale University. Dr. Emmons had finished his editorial work and written his Introduction before his lamented death in 1910; and the Volume contains his last words upon the subject to which he had given the work of his life, and on which he was justly regarded as the foremost authority.

*Contents.*

- Genesis of Certain Ore-Deposits. By S. F. EMMONS.  
 Structural Relations of Ore-Deposits. By S. F. EMMONS.  
 Geological Distribution of the Useful Metals in the United States. By S. F. EMMONS. Discussion, by JOHN A. CHURCH, ARTHUR WINSLOW, S. F. EMMONS, and WILLIAM HAMILTON MERRITT.  
 Torsional Theory of Joints. By GEORGE F. BECKER. Discussion, by H. M. HOWE, R. W. RAYMOND, C. R. BOYD, and GEORGE F. BECKER.  
 Allotropy of Gold. By HENRY LOUIS.  
 Superficial Alteration of Ore-Deposits. By R. A. F. PENROSE, JR.  
 Some Mines of Rosita and Silver Cliff, Colorado. By S. F. EMMONS.  
 Genesis of Certain Auriferous Lodes. By JOHN R. DON. Discussion, by JOSEPH LE CONTE, S. F. EMMONS, G. F. BECKER, ARTHUR WINSLOW, W. P. BLAKE, and J. R. DON.  
 Influence of Country-Rock on Mineral Veins. By WALTER HARVEY WEED.  
 Igneous Rocks and Circulating Waters as Factors in Ore-Deposition. By J. F. KEMP.  
 Consideration of Igneous Rocks and Their Segregation or Differentiation as Related to the Occurrence of Ores. By J. E. SPURR. Discussion, by A. N. WINCHELL.  
 Chemistry of Ore-Deposition. By WALTER P. JENNEY. Discussion, by JOHN A. CHURCH.  
 Ore-Deposits near Igneous Contacts. By WALTER HARVEY WEED. Discussion, by W. L. AUSTIN.  
 Ore-Deposition and Vein-Enrichment by Ascending Hot Waters. By WALTER HARVEY WEED.  
 Basaltic Zones as Guides to Ore-Deposits in the Cripple Creek District, Colorado. By E. A. STEVENS.  
 Geological Features of the Gold-Production of North America. By W. LINDGREN. Discussion, by W. G. MILLER and W. L. AUSTIN.  
 Osmosis as a Factor in Ore-Formation. By HALBERT POWERS GILLETTE.  
 Ore-Deposits of Sudbury, Ontario. By CHARLES W. DICKSON.  
 Genesis of the Copper-Deposits of Clifton-Morenci, Arizona. By W. LINDGREN.  
 Copper-Deposits at San Jose, Tamaulipas, Mexico. By J. F. KEMP.  
 Magmatic Origin of Vein-Forming Waters in Southeastern Alaska. By A. C. SPENCER.  
 Genetic Relations of the Western Nevada Ores. By J. E. SPURR.  
 Are the Quartz Veins of Silver Peak, Nevada, the Result of Magmatic Segregation? By J. B. HASTINGS.  
 Occurrence of Stibnite at Steamboat Springs, Nevada. By W. LINDGREN.  
 Summary of Lake Superior Geology with Special Reference to Recent Studies of the Iron-Bearing Series. By C. K. LEITH.  
 Geological Relations of the Scandinavian Iron-Ores. By H. SJÖGREN.  
 Formation and Enrichment of Ore-Bearing Veins. (With Supplementary Paper.) By GEORGE J. BANCROFT.  
 Distribution of the Elements in Igneous Rocks. By H. S. WASHINGTON.  
 Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold-Deposits of the United States. By W. H. EMMONS.  
 Cognate Papers.  
 Bibliography of the Science of Ore-Deposits. By J. D. IRVING, H. D. SMITH, and H. G. FERGUSON.

The volume contains 1002 pages. Price, bound in cloth, \$5; in half morocco, \$6. Both the Emmons and the Posepny Volumes on Ore-Deposits, bound in cloth, \$8; in half morocco, \$10.

## IRON AND STEEL COMMITTEE.

CHARLES KIRCHHOFF, *Chairman.*ALBERT SAUVEUR, *Vice-Chairman.*HERBERT M. BOYLSTON, *Secretary*, Abbot Bldg., Harvard Sq., Cambridge, Mass.

John Birkinbine,  
William H. Blauvelt,  
James Gayley,  
Henry D. Hibbard,  
Henry M. Howe,  
Robert W. Hunt,

J. E. Johnson, Jr.,  
William Kelly,  
Richard Moldenke,  
Joseph W. Richards,  
C. F. W. Rys,  
E. Gybbon Spilsbury,  
A. A. Stevenson,

J. S. Unger,  
Felix A. Vogel,  
Leonard Waldo,  
William R. Walker,  
William B. Webster,  
Frederick W. Wood.

J. S. Unger and C. F. W. Rys have accepted membership on the Iron and Steel Committee.

The Program Committee has held two meetings in New York and has perfected the preliminary plans for the October meeting. The Committee will meet again in September.

The following provisional program has been laid out by the Program Committee, but is subject to later additions and changes:

*First Session, Oct. 16, 10 A. M.*

1. W. A. Forbes, Blast Furnace Gas Cleaning.
2. ———.
3. W. R. Shimer, Over-Oxidation of Steel.
4. W. H. Blauvelt, The Slagging Producer.

*Second Session, Oct. 16, 2 P. M.*

5. H. F. Miller, Jr., New Design of Regenerators for Open-Hearth Furnaces.
6. Prof. F. Peter (Leoben, Austria), The Generation of Steam by Waste Heat from Furnaces.
7. G. C. Stone, The Generation of Steam by Waste Heat from Regenerative Furnaces.
8. Dr. Richard K. Meade, The Use of Powdered Coal as Fuel.
9. H. R. Barnhurst, The Use of Powdered Coal as Fuel for Metallurgical Furnaces.
10. E. Stütz, The Scoria Process for the Manufacture of Fine-Ore Briquettes.
11. Felix A. Vogel, Briquetting.
12. Felix A. Vogel, Use and Advantages of Briquettes in Blast-Furnace Practice.
13. R. H. Lee, The Use of Nodulized Ore in the Blast Furnace.

*Third Session, Oct. 17, 10 A. M.*

14. H. M. Howe and A. G. Levy, Determination of the Position of  $A_2$  in Carbon-Iron Alloys.
15. G. K. Burgess, J. J. Crowe, and H. S. Rawdon, Thermal and Microscopical Examination of Professor Howe's Standard Commercial Steels.
16. H. M. Howe, Discussion of the Existing Data as to the Position of  $A_2$ .
17. H. M. Howe,  $A_2$ , the Equilibrium Temperature for  $A_1$  in Carbon Steel.
18. H. M. Howe, The Divorcing of the Eutectoid in Meteorites.

*Fourth Session, Oct. 17, 2 P. M.*

19. R. R. Abbott, The Influence of Various Elements on the Absorption of Carbon Steel.
20. J. V. Emmons, Some Phases of the Practical Treatment of Tool Steel.
21. J. H. Hall, Shock Tests of Cast Steel.
22. G. H. Clevenger and B. Ray, The Influence of Copper upon the Physical Properties of Steel.
23. J. H. Hall, The Life of Crucible Steel Furnaces.

Some of these papers have already been printed in the *Bulletin* and it is expected that the others will be printed before the meeting.

A dinner for the men has been planned for the evening of Oct. 17, but the details have not yet been decided. After the dinner there will be a smoker and moving picture entertainment under the auspices of the New York Local Section.

H. M. BOYLSTON, *Secretary.*

## MONTANA LOCAL SECTION.

*Committee of Arrangement.*E. P. MATHEWSON, *Chairman.*FRANK M. SMITH, *Vice-Chairman.*D. C. BARD, *Secretary*, Montana State School of Mines, Butte, Mont.

OSCAR ROHN,

JAMES L. BRUCE.

On Aug. 20, 1913, the following 30 members of the Institute residing in Montana made written application to the Board of Directors of the Institute for authority to establish a local section of the Institute to be called the Montana Section, with headquarters at Butte, and having such territory as may later be determined on. This petition was granted by the Board at its meeting in Butte, Mont., Aug. 20, 1913. The committee named at the head of this paragraph was appointed to arrange for permanent organization of this section.

E. P. Mathewson,  
Reno H. Sales,  
William Scallon,  
August Christian,  
Frederick Laist,  
N. H. Emmons, 2d,  
Samuel Barker, Jr.,  
Theodore Simons,  
George E. Moulthrop,  
R. W. Rusterholz,  
Edgar M. Dunn,  
Willis T. Burns,  
C. W. Goodale,  
Ralph Hayden,  
Oscar Rohn,

C. F. Kelley,  
John R. Bartlett,  
M. H. Gidel,  
E. M. Norris,  
D. C. Bard,  
J. O. Elton,  
John Gillie,  
Charles W. Johnston,  
J. A. Grimes,  
Frederick T. Greene,  
J. H. Klepinger,  
W. A. Young,  
T. E. Mitchell,  
L. D. Frink,  
George A. Packard.

## THE COAL RESOURCES OF THE WORLD.

This book is an inquiry made upon the initiative of the Executive Committee of the Twelfth International Geological Congress, with the assistance of geological surveys and mining geologists of different countries, published by Morang & Co., Ltd., Toronto, Canada.

It consists of three quarto volumes of about 400 pages each, 8½ by 10½ in., and an atlas of about 70 maps in colors, 13½ by 19½ in., bound in heavy paper cover. Edition limited to 3,000 copies. One thousand copies will be reserved for members of the International Geological Congress, and the remainder of the edition will be distributed in the order in which applications are received. Price, \$25 per set.

## INTERNATIONAL ENGINEERING CONGRESS, 1915.

*Announcement.*

In connection with the Panama-Pacific International Exposition which will be held in San Francisco in 1915, there will be an International Engineering Congress, in which engineers throughout the world will be invited to participate.

The Congress is to be conducted under the auspices of the following five National Engineering Societies: American Society of Civil Engineers, American Institute of Mining Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, and The Society of Naval Architects and Marine Engineers.

These societies, acting in co-operation, have appointed a permanent Committee of Management, consisting of the Presidents and Secretaries of each of these Societies, and eighteen members resident in San Francisco.

Thus constituted, the personnel of the Committee is as follows:

*Representing the American Society of Civil Engineers.*

George F. Swain, *President.*

Charles Warren Hunt, *Secretary.*

Arthur L. Adams,  
W. A. Cattell,

Charles Derleth, Jr.,  
Charles D. Marr.

*Representing the American Institute of Mining Engineers.*

Charles F. Rand, *President.*

Bradley Stoughton, *Secretary.*

H. F. Bain,  
Edward H. Benjamin,

Newton Cleaveland,  
William S. Noyes.

*Representing the American Society of Mechanical Engineers.*

W. F. M. Goss, *President.*

Calvin W. Rice, *Secretary.*

W. F. Durand,  
R. S. Moore,

T. W. Ransom,  
C. R. Weymouth.

*Representing the American Institute of Electrical Engineers.*

Ralph Davenport Mershon, *President.*

F. L. Hutchinson, *Secretary.*

J. F. De Remer,

A. M. Hunt.

*Representing the Society of Naval Architects and Marine Engineers.*

Robert M. Thompson, *President.*

D. H. Cox, *Secretary.*

George W. Dickie,  
W. G. Dodd,

William R. Eckart,  
H. P. Frear.

The Committee has effected a permanent organization, with Prof. William F. Durand as Chairman, and W. A. Cattell as Secretary-Treasurer, and has established executive offices in the Foxcroft Building, 68 Post Street, San Francisco.

The ten members of the Committee, consisting of the Presidents and Secretaries of the five national societies, will constitute a Committee on Participation, through whom all invitations to participate in the Congress will be issued to governments, engineering societies, and individuals.

The personnel of this Committee is as follows:

*Committee on Participation.*Charles F. Rand, *Chairman.*Charles Warren Hunt, *Secretary.*

D. H. Cox,  
W. F. M. Goss,  
F. L. Hutchinson,  
Ralph Davenport Mershon,

Calvin W. Rice,  
Bradley Stoughton,  
George F. Swain,  
Robert M. Thompson.

The actual management of the Congress and the work of securing and publishing papers will be in charge of the members of the Committee resident in San Francisco. The work of the Resident Members has been assigned to different sub-committees and Chairman Durand has made the following appointments:

*Executive Committee.*W. F. Durand, *Chairman, Ex officio.*W. A. Cattell, *Secretary, Ex officio.*

E. H. Benjamin,

W. G. Dodd,

A. M. Hunt.

*Finance Committee.*W. G. Dodd, *Chairman.*

Newton Cleaveland,

R. S. Moore.

*Papers Committee.*A. M. Hunt, *Chairman.*

A. L. Adams,  
H. F. Bain,  
G. W. Dickie,

W. R. Eckart,  
C. D. Marx,  
C. R. Weymouth.

*Publicity Committee.*W. A. Cattell, *Chairman.*

C. Derleth, Jr.,

W. S. Noyes,

T. W. Ransom.

*Local Affairs Committee.*E. H. Benjamin, *Chairman.*

J. G. De Remer,

H. P. Frear.

The Honorary Officers of the Congress will consist of a President and a number of Vice-Presidents selected from among the most distinguished engineers of this and foreign countries.

The papers presented at the Congress will naturally be divided into groups or sections. During the Congress each section will hold independent sessions, which will be presided over by a chairman eminent in the branches of engineering covered by his section.

The scope of the Congress has not as yet been definitely determined, but it is hoped to make it widely representative of the best engineering practice throughout the world, and it is intended that the papers, discussions and proceedings shall constitute an adequate review of the progress made during the past decade and an authoritative presentation of the latest developments and most approved practices in the various branches of engineering work.

The papers, which will be collected and published by the Congress, should form an invaluable engineering library, and it is intended that this publication shall be in such form and at such cost as to become available to the greatest possible number.

The various committees are now actively at work, and it is hoped that further and more definite announcements as to the membership fees, schedules of papers, etc., can be made in the very near future.

## AFFILIATED STUDENT SOCIETIES.

Any society of undergraduates at a technical school, comprising students in any branch of engineering, metallurgy, chemistry, geology, etc., may be recognized by the Board of Directors in its discretion as an Affiliated Student Society. A circular giving details of the plan of affiliation may be obtained on application to the office of the Secretary of the Institute.

The following societies have been placed by authority of the Board of Directors on the above list:

### AFFILIATED STUDENT SOCIETIES.

The Mining Society of the Sheffield Scientific School, Yale University, New Haven, Conn. *President*, Francis S. Winslow; *Secretary*, Roger W. Newberry.

The University of Illinois Student Branch of the American Institute of Mining Engineers, Champaign, Ill. *President*, M. L. Nebel; *Secretary*, Willis Leriche.

The Engineering Society of the University of Nevada, Reno, Nev. *President*, P. E. Raymond; *Secretary*, R. M. Seaton.

The University of Wisconsin Mining Club, Madison, Wis. *President*, Rudolph J. Stengl; *Secretary*, Mack C. Lake.

The Mining and Geological Society of Lehigh University, South Bethlehem, Pa. *President*, Robert C. Mickel; *Secretary*, Edward B. Snyder.

The School of Mines Society of the University of Minnesota, Minneapolis, Minn. *President*, C. A. Walker; *Secretary*, A. C. Bierman.

The Mining Engineering Society of the Massachusetts Institute of Technology. *President*, Ralph E. Wells, Jr.; *Secretary*, Louis W. Currier.

The Student Auxiliary Society of the American Institute of Mining Engineers of the University of Kansas, Lawrence, Kan. *President*, Walter E. Rohrer; *Secretary*, H. R. Brown.

The Associated Miners of the University of Idaho, Moscow, Idaho. *President*, Hallard W. Foester; *Secretary*, Walter P. Scott.

The State College of Washington Mining and Geological Society, Pullman, Wash. *President*, J. V. Quigley; *Secretary*, S. A. Swanson.

The Tejas Technical Society, School of Mines, University of Texas, Austin, Tex. *President*, G. C. Cartwright; *Secretary*, David S. Alley.

The Ohio State University Student Branch of the American Institute of Mining Engineers, Columbus, Ohio. *President*, Hugh B. Lee; *Secretary*, E. P. Elliott.

The Stanford Geology and Mining Society, Stanford University, Cal. *President*, B. E. Parsons; *Secretary*, E. D. Nolan.

The Senior Mining Society of Columbia University, New York, N. Y. *President*, Roger L. Strobel; *Secretary*, Clark G. Mitchell.

Mining Association of the University of California, Berkeley, Cal. *President*, D. M. Drumheller, Jr.; *Secretary*, J. B. Orynski.

Tufts College Chemical Society, Tufts College, Mass. *President*, P. G. Savage; *Secretary*, W. S. Frost.

University of Washington Mining Society, Seattle, Wash. *President*, Oliver P. Searing; *Secretary*, Albert R. Sherman.

Student Branch of the American Institute of Mining Engineers, Iowa State College, Ames, Iowa. *President*, Lyle A. Butler; *Secretary*, A. J. Crawford.

Missouri Mining Association of the Missouri School of Mines, Rolla, Mo. *President*, L. S. Copelin; *Secretary*, L. J. Boucher.

The Pick and Shovel Club of the Case School of Applied Science, Cleveland, Ohio. *President*, M. T. Whelan; *Secretary*, Lloyd A. Collier.

Colorado School of Mines Scientific Society, Golden, Colo. *President*, Alan Kissock; *Secretary*, George Wilfley.

Mining Engineering Society of the University of Arizona, Tucson, Ariz. *President*, J. Gary Lindley; *Secretary*, H. O. Coles.

Kentucky Mining Society, College of Mines and Metallurgy, University of Kentucky, Lexington, Ky. *President*, Oliver W. Smith; *Secretary*, Charles E. Straub.

Mining Society of Pennsylvania State College, State College, Pa. *President*, Ralph E. Kirk; *Secretary*, Willard M. Lindsey.



## LIBRARY.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

AMERICAN INSTITUTE OF MINING ENGINEERS.

UNITED ENGINEERING SOCIETY.

WILLIAM P. CUTTER, Librarian.

The Library of the above-named Societies is open from 9 A.M. to 9 P.M. on all week-days, except holidays, from September 1 to June 30, and from 9 A.M. to 6 P.M. during July and August. The Library contains about 55,000 volumes, including sets of technical periodicals and the publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library can render valuable service through correspondence; letters requesting information will receive special attention. The Library is prepared to furnish references and copies of articles on mining and metallurgical subjects; to determine the existence of mining-maps, and to furnish general information as to the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

The members of the Institute can be of service to the Library by forwarding copies of mining-reports, maps privately issued, and similar material, which will be classified, indexed, and made available to other members. Suggestions for additions to the Library, either by purchase or personal solicitation as gifts, will be welcomed. It is hoped that members while in the city will use the Library freely, and assurance is given that most careful service will be rendered to them.

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## LIBRARY RESEARCH-WORK.

During the year 1912 there were 160 searches made for members and non-members of the Founder Societies, and copies of the references have been preserved for the use of others. This work has been largely based on requests sent in by mail, from Japan, South Africa, South America, Mexico, Canada, and England, as well as from different parts of the United States. The library receives 670 technical periodicals which are available through the indexes for this special purpose.

## Library Accessions.

July 1 to Aug. 15, 1913.

[Copies of the list of additions to the Libraries of the American Society of Mechanical Engineers and the American Institute of Electrical Engineers can be obtained on application to the Secretary of the American Institute of Mining Engineers.]

- AERISS DER ERZLAGERSTÄTTENKUNDE.** By A. Bergeat. Jena, 1913. (Purchase.)
- AMALGAMATED SOCIETY OF ENGINEERS.** Annual Report, 62d, 1912. London, 1912. (Gift of Amalgamated Society of Engineers.)
- AMERICAN ELECTROCHEMICAL SOCIETY.** Transactions, vol. XXIII. South Bethlehem, 1913. (Exchange.)
- AMERICAN FOUNDRYMEN'S ASSOCIATION.** Constitution and Membership List. Watchung, 1913. (Exchange.)
- AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.** Transactions, vol. V., 1912. New York, 1913. (Exchange.)
- AMERICAN MINING CONGRESS.** Report of Proceedings, 15th Annual Session, 1912. Denver, 1913. (Exchange.)
- ANALYSIS OF BLACK POWDER AND DYNAMITE.** (Bulletin No. 51, U. S. Bureau of Mines. Washington, 1913. (Exchange.)
- ASOCIACION DE INGENIEROS Y ARQUITECTOS DE MEXICO.** Anales, tomo XX. Mexico, 1913.
- *Lista de los Socios que Formaban parte de dicha asociacion en 1 de Enero de 1913.* Mexico, 1913. (Exchange.)
- ASSOCIATION DES INGÉNIEURS SORTIS DE L'ECOLE DE LIÈGE.** Liste des Membres, 1913. Liège, 1913. (Exchange.)
- BEITRÄGE ZUR IDENTIFIZIERUNG UND KENNTNIS DER KOHLENWASSERSTOFFE DES ERDÖLS.** By Jenő Tausz. Borna-Leipzig, 1912. (Purchase.)
- BIJDRAGE TOT DE KENNIS DER KATALYSE.** By H. J. Prins. N. p., 1912. (Gift of Technische Hoogeschool te Delft.)
- BRITISH COLUMBIA. MINISTER OF MINES.** Annual Report, 1912. Victoria, 1913.
- *Map of British Columbia.* 1913. (Gift of British Columbia Minister of Mines.)
- CALIFORNIA MINERS' ASSOCIATION.** Proceedings of 16th Annual Convention. San Francisco, 1912. (Gift of Association.)
- CANADA. (QUEBEC). DEPARTMENT OF COLONIZATION, MINES AND FISHERIES.** Extracts from reports on the district of Ungava. Quebec, 1913. (Exchange.)
- CANADIAN SOCIETY OF CIVIL ENGINEERS.** Charter, By-Laws and List of Members, 1913. Montreal, 1913. (Exchange.)
- CARNEGIE LIBRARY OF PITTSBURG.** Annual Report, 17th, 1913. Pittsburg, 1913. (Exchange.)
- CARNEGIE MUSEUM OF PITTSBURG.** Annual Report of the Director, 1913. Pittsburg, 1913. (Gift of Museum.)
- COAL DUST EXPLOSION TESTS IN THE EXPERIMENTAL MINE, FIRST SERIES.** (Bulletin 56, U. S. Bureau of Mines. Washington, 1913. (Exchange.)
- CONGRESO CIENTIFICO (1° PAN AMERICANO).** Derecho Internacional constitucional e Historia. (Volumen XX.) Santiago de Chile, 1912. (Gift of Congreso Científico.)
- CONNECTICUT. GEOLOGICAL AND NATURAL HISTORY SURVEY.** Biennial Report, 4th, 5th. (Bulletin Nos. 17, 21.) Hartford, 1910, 1912. (Exchange.)
- CONTRIBUTIONS TO THE STUDY OF THE GEOLOGY AND ORE DEPOSITS OF KALGOORLIE, EAST COOLGARDIE GOLDFIELD.** Part I. Bulletin No. 42, Western Australia Geological Survey. Perth, 1912. (Exchange.)
- DARTMOUTH COLLEGE.** Charter, Historical Sketch and Views of College Buildings. Hanover, 1912.
- *Catalogue, 1912-13.* Hanover, 1912. (Exchange.)
- ELECTRIC FURNACES IN THE IRON AND STEEL INDUSTRY.** By W. Rodenhauser and I. Schoenawa. New York, 1913. (Purchase.)

- ELECTROLYTIC METHOD OF PREVENTING CORROSION OF IRON AND STEEL. (Technical Paper 15.) Washington, 1913. (Exchange.)
- GEOLOGICAL HISTORY OF THE YELLOWSTONE NATIONAL PARK. Washington, 1912. (Gift of U. S. Dept. of Interior.)
- GEOLOGY AND ORE DEPOSITS OF THE PHILIPSBURG QUADRANGLE, MONTANA. (Professional Paper No. 78, U. S. Geological Survey.) Washington, 1913. (Purchase.)
- GEOLOGY OF THE GOLD BELT IN THE JAMES RIVER BASIN, VIRGINIA. (Bulletin No. VII, Virginia Geological Survey.) Charlottesville, 1912. (Exchange.)
- GEORGIA. GEOLOGICAL SURVEY. Bulletin No. 20. Atlanta, 1913. (Exchange.)
- GETSERS. Washington, 1912. (Gift of U. S. Dept. of Interior.)
- HEAVY OIL AS FUEL FOR INTERNAL COMBUSTION ENGINES. (Technical Paper No. 37, U. S. Bureau of Mines. Washington, 1913. (Exchange.)
- HET SOCIALE ARBEIDSCONTRACT. By J. Van Hettinga Tromp. Amsterdam, 1913. (Gift of Technische Hoogeschool te Delft.)
- HOEKIJZERVERBINDINGEN IN HET BIJZONDER DIE DER LANGS-AAN DWARSDRAGERS IN BRUGGEN. By J. H. A. Haarman. N. p., n. d. (Gift of Technische Hoogeschool te Delft.)
- INDIA. GEOLOGICAL SURVEY. Memoirs, vol. XLI. Calcutta, 1913. (Exchange.)
- INSTITUTE OF METALS. Journal, vol. IX. London, 1913. (Exchange.)
- IRON AND STEEL INSTITUTE. Carnegie Scholarship Memoirs, vol. V. London, 1913. (Exchange.)
- JAHRES-BERICHT UBER DIE LEISTUNGEN DER CHEMISCHEN TECHNOLOGIE FÜR DAS JAHR, 1912. 1<sup>te</sup> Abteilung: anorganischer Teil. Leipzig, 1913. (Purchase.)
- KANSAS ENGINEERING SOCIETY. Transactions, 1912. N. p., 1912. (Gift of Kansas Engineering Society.)
- KÖNIGLICH PREUSSISCHEN GEOLOGISCHEN LANDESANSTALT ZU BERLIN. JAHRBUCH, vol. XXX., pt. II., 1909; XXIII., Teil I., pts. 1-2, 1912. Berlin, 1912. (Exchange.)
- KOYUKUK-CHANDALAR REGION, ALASKA. (Bulletin No. 532, U. S. Geological Survey.) Washington, 1913. (Exchange.)
- LIQUID STEEL, Its Manufacture and Cost. By David Carnegie and S. C. Gladwyn. New York, 1913. (Purchase.)
- METAL STATICS, 1913. Sixth annual edition. New York, 1913. (Gift of American Metal Market Co.)
- METALLBANK UND METALLURGISCHE GESELLSCHAFT. Statistische Zusammenstellungen über Blei, Kupfer, Zink, Zinn, Aluminium, Nickel, 19 Jahrgang, 1903-1912. Frankfurt am Main, 1913. (Gift of Metallgesellschaft.)
- MICHIGAN COLLEGE OF MINES. Year Book, 1912-13. Houghton, 1913. (Exchange.)
- NATIONAL PARK CONFERENCE. Proceedings, Sept. 11-12, 1911. Washington, 1912. (Gift of U. S. Dept. of Interior.)
- NATURAL GAS SERVICE. By S. S. Wyer. Columbus, 1913. (Gift of Author.)
- NEW SOUTH WALES. Department of Mines. Annual Report, 1912. Sydney, 1913. (Exchange.)
- Mineral Resources, No. 17. Sydney, 1913. (Exchange.)
- NEW ZEALAND INSTITUTE. Transactions and Proceedings, vol. XLV. Wellington, 1913. (Exchange.)
- NICKEL INDUSTRY, with special reference to the Sudbury Region, Ontario. By A. P. Coleman. Ottawa, 1913. (Exchange.)
- NORTH CAROLINA. GEOLOGICAL AND ECONOMIC SURVEY. Report, vol. III. Raleigh, 1912. (Exchange.)
- OKLAHOMA GEOLOGICAL SURVEY. Circular Nos. 4, 5. Norman, 1913. (Exchange.)
- OVER ENIGE FACTOREN, DIE DE ONTWIKKELING VAN *PENICILLIUM GLAUCUM* BEÏNVOEDEN. By H. I. Waterman. N. p., 1913. (Gift of Technische Hoogeschool te Delft.)
- OVERHEIDSBEMOEIINGEN MET STEDEBOUW TOT AAN DEN VREDE VAN MUNSTER. By W. B. Peteri. N. p., 1913. (Gift of Technische Hoogeschool te Delft.)
- REPORT ON THE COBAR COPPER AND GOLD FIELD. Part I., with maps. (New South Wales. Department of Mines. Mineral Resources, No. 17.) Sydney, 1913. (Exchange.)
- RHODESIA CHAMBER OF MINES. (Annual Report, 18th, 1912. Bulawayo, 1913. (Exchange.)

- ROCK ASPHALTS OF OKLAHOMA AND THEIR USE IN PAVING. (Circular No. 5, Oklahoma Geological Survey. Norman, 1913. (Exchange.)
- ROYAL INSTITUTE OF BRITISH ARCHITECTS. Report of the Council, 1912, list of donors and annual subscribers, Architects Benevolent Society. London, 1913. (Exchange.)
- SAFETY ELECTRIC SWITCHES FOR MINES. (Technical Paper No. 44, U. S. Bureau of Mines.) Washington, 1913. (Exchange.)
- SKETCH OF YOSEMITE NATIONAL PARK, and an account of the origin of the Yosemite and Hetch Hetchy valleys. Washington, 1912. (Gift of U. S. Dept. of Interior.)
- SNELHEIDSMETINGEN BIJ DE REACTIE VAN FRIEDEL EN CRAFTS. By S. C. J. Olivier. N. p., n. d. (Gift of Technische Hoogeschool te Delft.)
- SOCIÉTÉ L'INDUSTRIE MINÉRALE. Annuaire, 1913-14. Saint-Etienne, 1912. (Exchange.)
- SOME LAKES OF GLACIER NATIONAL PARK. Washington, 1912. (Gift of U. S. Dept. of Interior.)
- STANDARD MINING CO. Report on the Properties of. Arizona, 1913. (Gift of Kirby Thomas.)
- SURVEYORS' INSTITUTION. List of Members, 1913. Westminster, 1913. (Exchange.)
- SYDNEY COAL FIELDS, CAPE BRETON. Sections of the. By J. G. S. Hudson. Ottawa, 1913. (Exchange.)
- TASMANIA. DEPARTMENT OF MINES. Geological Survey Bulletin No. 13. Tasmania, 1913. (Gift of Department of Mines.)
- TEKTONISCHE UND STRATIGRAPHISCHE BEOBSACHTUNGEN AM SÜDWESTSTRANDE DES LIMBURGISCHEN KOHLENREVIERES. By W. C. Klein. N. p., 1913. (Gift of Technische Hoogeschool te Delft.)
- U. S. BUREAU OF MINES. Bulletin Nos. 51, 54, 56. Washington, 1913. (Exchange.)
- Technical Paper Nos. 15, 37, 44, 49. Washington, 1913. (Exchange.)
- U. S. COMMISSIONER OF CORPORATIONS. Report on the Steel Industry. Part III., Cost of Production. Washington, 1913. (Gift of Department of Commerce.)
- U. S. GEOLOGICAL SURVEY. Bulletin Nos. 532, 534. Washington, 1913. (Exchange.)
- Professional Paper No. 78. Washington, 1913. (Exchange.)
- Water Supply Paper No. 318. Washington, 1913. (Exchange.)
- U. S. NATIONAL MUSEUM. Bulletin No. 81. Washington, 1913. (Exchange.)
- U. S. ORDNANCE DEPARTMENT. Report of the Tests of Metals, 1912. Washington, 1913.
- Index to the Reports of the Tests of Metals, 1881-1912. Washington, 1913. (Exchange.)
- LA VIE INTERNATIONALE. Tome III., fascicule II, 1913. Bruxelles, n. d. (Gift.)
- VIRGINIA GEOLOGICAL SURVEY. Bulletin No. VII. Charlottesville, 1913. (Exchange.)
- WATER RESOURCES OF HAWAII, 1909-1911. (Water Supply Paper No. 318, U. S. Geological Survey. Washington, 1913. (Exchange.)
- WESTERN AUSTRALIA. GEOLOGICAL SURVEY. Bulletin No. 42. Perth, 1912. (Exchange.)
- YENTNA DISTRICT, ALASKA. (Bulletin No. 534, U. S. Geological Survey. Washington, 1913. (Exchange.)
- YUKONITE, a new hydrous arsenate of iron and calcium, from Tagish Lake, Yukon Territory, Canada; with a note on the associated symplectite. By J. B. Tyrrell. Ottawa, 1913. (Gift of Author.)

## GIFT OF HILL PUBLISHING CO.

- ALASKA GOLD MINES CO. Annual Report, 1st, 1912.
- ANACONDA COPPER MINING CO. Report for the year ending Dec. 31, 1912.
- BERGIUS, FRIEDRICH. Die Anwendung hoher Brucke bei chemischen Vorgängen und eine Nachbildung des Entstehungsprozesses der Steinkohle. Halle, 1913.
- GRANBY CONSOLIDATED MINING, SMELTING AND POWER CO., LTD. Report, 1912.
- LECOMTE-DENIS, M. Comment on Crée une Mine. Ed. 10. Paris, n. d.
- MARGOSCHES, B. M. Die Chemische Analyse. Band XIV-XV. Stuttgart, 1912.
- MASON VALLEY MINES CO. Annual Report, 3d, 1912.
- MINING JOURNAL (RUSSIAN). Jan.-March, 1913.
- MODDERFONTEIN DEEP LEVELS, LTD. Annual Report, 13th, 1912.

- MOUNT MORGAN GOLD MINING CO., LTD. Directors' Report to the Shareholders, for half year ended Nov. 20, 1912.
- QUINCY MINING CO. Report, 1912.
- SLIME FILTRATION AND CYANIDING. London, n. d.
- STEWART MINING CO. Report on operations of, in the Cœur D'Alènes, June-Dec., 1912.
- TONOPAH BELMONT DEVELOPMENT CO. Annual Report, 10th, 1913.
- UTAH COPPER CO. Annual Report, 8th, 1912.
- Quarterly Report, 20th, 1913.
- U. S. EDUCATION COMMISSIONER. Report, vols. I-II, 1912. Washington, 1913.
- VAN RYN GOLD MINES ESTATE, LTD. Directors' Report, 1912.
- VEREINIGTE KÖNIGS- UND LAURAHÜTTE AKTIEN-GESELLSCHAFT FÜR BERGBAU U. HÜTTENBETRIEB. Bericht über das Geschäftsjahr, 1909-10.

## TRADE CATALOGUES.

- BAKER, J. T., CHEMICAL CO. Phillipsburg, N. J. Price list of Baker's analyzed chemicals, June, 1913.
- BUCKEYE ENGINE CO., Salem, Ohio. Bulletin No. 10-B. Buckeye-mobile, July, 1913.
- INGERSOLL-RAND CO., New York, N. Y. Catalogue of Products, June, 1913.
- LESCHEN, A. & SONS ROPE CO., St. Louis, Mo. Leschen's Hercules, July, Aug., 1913.
- WEBSTER MFG. CO., Tiffin, O. Webster method, July, 1913.

## United Engineering Society Library.

- ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS CONVENTION. Structural steel poles and towers. By R. Fleming. N. p., n. d. (Gift of Author.)
- CAMBRIA STEEL. Handbook of Information relating to Structural Steel Manufactured by the Cambria Steel Co. Johnstown, 1912. (Gift of Cambria Steel Co.)
- CHRONOLOGY OF AVIATION. By Hudson Maxim and W. J. Hammer. (Reprinted from *World Almanac* for 1911.) (Gift of W. J. Hammer.)
- COLUMBIA UNIVERSITY. Catalogue of Officers and Graduates from 1754-1912. New York, 1912. (Gift of Columbia University.)
- EFFICIENCY SOCIETY. Transactions, vol. I., 1912. New York, 1913. (Gift of Efficiency Society.)
- INTERNATIONAL ACETYLENE ASSOCIATION. Report of Annual Convention, 14th, 15th. Chicago, 1911-12. (Gift of Association.)
- MOODY'S MANUAL OF RAILROADS AND CORPORATION SECURITIES. Vol. II., 1913. New York, 1913. (Purchase.)
- PATENTE. Jahres-Katalog XXIV., Jahrgang, 1912. Brugg, 1913. (Purchase.)
- QUEENS BOROUGH PUBLIC LIBRARY. Report of the Chief Librarian for the year ending Dec. 31, 1912. New York, 1912. (Gift of Queens Borough Public Library.)

## MEMBERSHIP.

## NEW MEMBERS.

The following list comprises the names of those persons who became members during the months of July and August, 1913:

*Members.*

|                                                                                        |                                                       |
|----------------------------------------------------------------------------------------|-------------------------------------------------------|
| ALDERSON, VICTOR C., Prest. of Colorado School of Mines.....                           | Golden, Colo.                                         |
| ALLEN, JOSEPH W., Secy. & Treas. International S. & R. Co.,                            | 42 Broadway, New York, N. Y.                          |
| AMMON, ROBERT, Chief Sampler B. & M. Reduction Wks., Anaconda Copper Min. Co.,         | Great Falls, Mont.                                    |
| BARBER, RAYMOND J., Min. Engr.....                                                     | 234 Newbury St., Boston, Mass.                        |
| BARDWELL, EARL S., Genl. Concentrator Foreman Boston & Mont. Reduction Plant,          | Great Falls, Mont.                                    |
| BARKER, PIERCE, Met., Anaconda Copper Min. Co.....                                     | P. O. Box 361, Anaconda, Mont.                        |
| BACHELLOR, STILLMAN, Min. Engr.....                                                    | 1a San Augustin No. 12, Mexico City, Mexico.          |
| BEATON, NORMAN H., Min. Engr.....                                                      | 305 Chamber of Commerce, Denver, Colo.                |
| BEDDALL, THOMAS H., Min. Engr.....                                                     | P. O. Box 163, Irwin, Pa.                             |
| BEERS, ALBERT D., Ore Dept. New Jersey Zinc Co.....                                    | 55 Wall St., New York, N. Y.                          |
| BENDER, LOUIS V., Asst. Gen'l Supt.....                                                | Washoe Reduction Wks., Anaconda, Mont.                |
| BERRIAN, CHAUNCEY L., Supt. Mountain View Mine.....                                    | Butte, Mont.                                          |
| BISSELL, ROBERT W., Min. Engr.....                                                     | 435 W. 119th St., New York, N. Y.                     |
| BROWNSON, EDGAR E., Chief Chemist B. & M. Smelter.....                                 | Great Falls, Mont.                                    |
| BURFORD, JOSEPH S., JR., Gold & Silver Assayer.....                                    | 23 Pine St., New York, N. Y.                          |
| CAPLES, RUSSELL B., JR., Chem.....                                                     | Anaconda Club, Anaconda, Mont.                        |
| CARNAHAN, THOMAS S., Min. Engr.....                                                    | Bingham Canyon, Utah.                                 |
| CHANCELLOR, WILLIAM C., Met., McConway's & Torley Co., 48th St. and A. V. R. R.,       | Pittsburg, Pa.                                        |
| CLARK, HENRY, Engr.....                                                                | 84 Moss St., Victoria, B. C., Canada.                 |
| CLARKE, SIMON S., Min. Engr.....                                                       | St. Joseph Lead Co., Leadwood, Mo.                    |
| COOPER, JOHN HENRY, Min. Engr.....                                                     | 2321 S. Flower St., Los Angeles, Cal.                 |
| CORSA, DEAN, Min. Engr., Vice-Prest. & Gen'l Mgr. Wytheville Iron Co., Wytheville, Va. | 900 5th Avenue, N., Great Falls, Mont.                |
| CORWIN, FRANK R., Smelter Foreman.....                                                 | 26 Smelter Hill, Great Falls, Mont.                   |
| CROWFOOT, ARTHUR, Asst. Gen'l Smelter Foreman.....                                     | 608 Kingsley St., Palo Alto, Cal.                     |
| DIETRICH, WALDEMAR F., Min. Engr.....                                                  | 608 Kingsley St., Palo Alto, Cal.                     |
| FAHRENWALD, FRANK A., Min. Engr.....                                                   | Rapid City, S. D.                                     |
| FEELER, JOHN C., Chemist.....                                                          | P. O. Box 105, Butte, Mont.                           |
| FORBES, CARROLL R., Prof. of Min.....                                                  | School of Mining and Met., Rolla, Mo.                 |
| FORBES, WILLIAM A., Met.....                                                           | Room 1605, 71 Broadway, New York, N. Y.               |
| FOSS, THEODORE, Min. and Met. Engr.....                                                | Manejnii Pereouluk 16, St. Petersburg, Russia.        |
| FRICK, FREDERICK F., Testing Engr.....                                                 | P. O. Box 294, Anaconda, Mont.                        |
| GATES, ARTHUR O., Instructor.....                                                      | Purdue University, 1017 State St., La Fayette, Ind.   |
| GIDEL, MURL H., Geol.....                                                              | 1120 W. Galena St., Butte, Mont.                      |
| GITTINS, ARTHUR W., Asst. Supt. of Blast Furnace.....                                  | 606 Braddock Ave., Pittsburg, Pa.                     |
| GRIMES, JOHN A., Geol.....                                                             | Leonard Hotel, Butte, Mont.                           |
| HAIGHT, CLARENCE M., Min. Engr.....                                                    | Franklin Furnace, N. J.                               |
| HAYDEN, RALPH, Asst. Supt. of Concentrator, Washoe Reduction Wks., Anaconda, Mont.     |                                                       |
| HEBGEN, MAX, Vice-Prest. and Genl. Mgr., Mountain Power Co.,                           | 500 W. Broadway, Butte, Mont.                         |
| HENRY, PHILIP W., Cons. Engr.....                                                      | 25 Broad St., New York, N. Y.                         |
| HILTON, HOWARD J., Min. Engr.....                                                      | Ray Cons. Copper Co., Ray, Ariz.                      |
| HODGKINS, ARTHUR E., Mining Iron Ore.....                                              | Port Henry, N. Y.                                     |
| JOHNSTON, CHARLES W., Min. Engr.....                                                   | 515 N. Emmet Ave., Butte, Mont.                       |
| JONES, LLEWELLYN W., Works Mgr., Taylor-Wharton Iron & Steel Co.,                      | High Bridge, N. J.                                    |
| LEACH, ROBERT H., Min. Engr.....                                                       | 58 Main St., Brockton, Mass.                          |
| MCGEE, GEORGE F., Min. Mgr.....                                                        | Helena, Mont.                                         |
| MITCHELL, THOMAS E., Asst. Genl. Supt. of Mines, Anaconda Copper Mining Co.            | Butte, Mont.                                          |
| MOFFAT, DAVID D.....                                                                   | Supt. of Magna Plant Utah Copper Co., Garfield, Utah. |
| MURPHY, JAMES K., Met.....                                                             | Anaconda, Mont.                                       |
| O'NEIL, FREDERICK W., Mgr. of Sales, Nordberg Mfg. Co., 285 Lyon St.,                  | Milwaukee, Wis.                                       |

|                                                                                                           |                                                          |
|-----------------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| PAGE, WILLIAM K., Met. Engr.....                                                                          | Room 1711, 165 Broadway, New York, N. Y.                 |
| PERRY, HAROLD R., Instructor.....                                                                         | 296 Norfolk St., Dorchester, Mass.                       |
| RAY, HORATIO C.....                                                                                       | School of Mines, University of Pittsburg, Pittsburg, Pa. |
| RISQUE, JAMES B., Mgr.....                                                                                | Tenn. Copper Co., Copperhill, Tenn.                      |
| ROOT, JOHN A., Chem.....                                                                                  | P. O. Box 443, Anaconda, Mont.                           |
| ROSS, LOUIS, Cons. Engr.....                                                                              | 79 Milk St., Boston, Mass.                               |
| SIMONS, THEODORE, Prof. Min. Engineering, Montana State School of Mines, Butte, Mont.                     |                                                          |
| STEINMESCH, JESSE H., Asst. Supt.....                                                                     | Dealoge Cons. Lead Co., Dealoga, Mo.                     |
| STÜTZ, ERNEST, Patent Sales Agent.....                                                                    | 437 Fifth Ave., New York, N. Y.                          |
| THOMAS, GEORGE S., Asst. in Testing Dept., Washoe Smelter, Box 364, Anaconda, Mont.                       |                                                          |
| THOMPSON, ARTHUR P., Geol.....                                                                            | 526 Hennessy Bldg., Butte, Mont.                         |
| THOMPSON, J. FRANK, Asst. Supt.....                                                                       | St. Louis S. & R. Co., St. Francois, Mo.                 |
| TREMOUREAUX, ROY E., Asst. Supt.....                                                                      | North Star Mines, Nevada City, Cal.                      |
| VAN ELLS, HENRY T., Statistician.....                                                                     | Room 2150, 42 Broadway, New York, N. Y.                  |
| VAUGHAN, FRANCIS E., Min. Engr.....                                                                       | Copper Queen Cons. Mining Co., Bisbee, Ariz.             |
| WATT, ARTHUR P., Supt. of Concentrator, Balbach Smelting & Refining Co.,<br>580 Market St., Newark, N. J. |                                                          |
| WANDER, ERNEST, Met.....                                                                                  | Missouri Iron Co., Waukon, Iowa.                         |
| WARD, HARRY J., Vice-Prest. and Supt....                                                                  | Ward-Dickey Steel Co., Indiana Harbor, Ind.              |
| WELLS, PEARSON, Efficiency Engr.....                                                                      | Newport Mining Co., Ironwood, Mich.                      |
| WESTERVELT, EDWARD W., Min. Engr.....                                                                     | Ray, Ariz.                                               |
| WHITE, ISRAEL C., Geol.....                                                                               | Morgantown, W. Va.                                       |
| WICKS, FRANK R., Mill Supt., Butte & Superior Copper Co., P. O. Box 1425, Butte, Mont.                    |                                                          |
| WITHERBEE, SILAS H., Mining.....                                                                          | Port Henry, N. Y.                                        |
| WOHLER, ALOYS H., Min. Engr.....                                                                          | Isle Royal Copper Co., Houghton, Mich.                   |
| WOODHOUSE, CHARLES C., JR., Min. Engr., Met.....                                                          | Republic, Wash.                                          |
| WYMAN, GEORGE H., JR., Min. Engr.....                                                                     | Wallace, Idaho.                                          |
| YOUNG, WILLIAM A., Min. Engr.....                                                                         | Lewistown, Mont.                                         |
| ZENTNER, ARTHUR A., Met. and Chem.....                                                                    | P. O. Box 65, Anaconda, Mont.                            |

*Associates.*

|                                                                                                                |                                                     |
|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| BOLGHIANO, J. RALPH, Sales Engr., Taylor-Wharton Iron & Steel Co.,<br>105 W. Monroe St., Chicago, Ill.         |                                                     |
| BOYLE, CLARENCE, JR., Dist. Mgr., Taylor-Wharton Iron & Steel Co.,<br>522 Cornell Bldg., Scranton, Pa.         |                                                     |
| CHAPMAN, RICHARD D., Sales Agt., Taylor-Wharton Iron & Steel Co.,<br>504 Newhouse Bldg., Salt Lake City, Utah. |                                                     |
| DYE, ALEXANDER, Secy. and Gen'l Mgr.....                                                                       | Phelps, Dodge & Co., Bisbee, Ariz.                  |
| GAYLORD, HAROLD B., Mgr.....                                                                                   | 30 Church St., New York, N. Y.                      |
| HAZARD, ARCHIE M., Mine Supt.....                                                                              | Casilla 5, La Paz, Bolivia, So. Amer.               |
| HINTERLEITNER, HENRY J., Asst. to Gen'l Mgr., Clearfield Bit. Coal Corp.,<br>Clearfield, Pa.                   |                                                     |
| LINEAWEAVER, HENRY H., Coal.....                                                                               | 1009 West End Trust Bldg., Philadelphia, Pa.        |
| MORRISON, JAMES S., Dist. Sales Mgr.....                                                                       | 1418 Oliver Bldg., Pittsburg, Pa.                   |
| NARAYANE, SHANKAR G., Student.....                                                                             | 331 East 51st St., New York, N. Y.                  |
| NORDBERG, BRUNO V., Mech. Engr.....                                                                            | 512 Logan Ave., Milwaukee, Wis.                     |
| SIEDLER, GEORGE J., Sales Mgr.....                                                                             | Taylor-Wharton Iron & Steel Co., High Bridge, N. J. |
| STOTHOFF, WILLIAM S., Sales Mgr.....                                                                           | High Bridge, N. J.                                  |
| WELBORN, JESSE F., Prest.....                                                                                  | Colorado Fuel & Iron Co., Denver, Colo.             |
| WRIGHT, WILFRED L., Vice-Prest. Tioga Steel & Iron Co., Land Title Bldg.,<br>Philadelphia, Pa.                 |                                                     |

*Junior Members.*

|                                                  |                                        |
|--------------------------------------------------|----------------------------------------|
| ABRAHAMS, ALEXANDER I., Student.....             | McGill, Nev.                           |
| CAHEN, JAMES PHILIP, JR., Mining Student.....    | 353 Central Park West, New York, N. Y. |
| CABUTHERS, ANTHONY W., D. L. & W. Coal Dept..... | 231 Chestnut St., Kingston, Pa.        |
| DICKEL, ARNOLD C., Mine Engr.....                | 1711 Euclid Ave., Berkeley, Cal.       |
| HES, K. F., Asst. Stope Engr.....                | Ray Cons. Copper Co., Ray, Ariz.       |
| LUNN, ROBERT, JR., Student.....                  | 70 Brinkerhoff St., Jersey City, N. J. |
| MEANS, ALAN H., Student.....                     | 32 St. James Ave., Boston, Mass.       |
| PATCHELL, FREDERICK J., Min. Engr.....           | Copper Cliff, Ont., Canada.            |
| PROCHAZKA, GEORGE A., JR.....                    | Hibbing, Minn.                         |

|                                                                                    |                                                     |
|------------------------------------------------------------------------------------|-----------------------------------------------------|
| PYNE, WALTER F., Student.....                                                      | 614 W. 114th St., New York, N. Y.                   |
| SCHMIDT, WILLIAM C., Jr., Student School of Mines, Columbia Univ., New York, N. Y. |                                                     |
| THOMPSON, R. VICTOR, Assayer.....                                                  | Hilltop, Lander Co., Nevada.                        |
| TRISCHKA, CARL, Min. Engr.....                                                     | P. O. Box 485, Bisbee, Ariz.                        |
| WENDEL, EDMUND.....                                                                | Testing Laboratory, Washoe Smelter, Anaconda, Mont. |
| WISE, ALFRED L., Min. Engr.....                                                    | 28 East 63d St., New York, N. Y.                    |
| WOOD, CARL L., Met.....                                                            | 6013 Dipple Ave., Cleveland, Ohio.                  |

### CANDIDATES FOR MEMBERSHIP.

The following persons have been proposed during the period July 21 to Aug. 31, 1913, for election as members of the Institute. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

#### *Members.*

**John L. Agnew**, Copper Cliff, Ontario.

Proposed by G. M. Colvocoresses, G. E. Silvester, J. C. Nicholls.

Born, 1884, Pittsburg, Pa. 1902, High School. 1903, United Engineering & Foundry Co. 1904, Canadian Copper Co.

Present position: General Superintendent, Canadian Copper Co.

**Alan Mara Bateman**, Kingston, Ontario.

Proposed by L. C. Graton, Reno H. Sales, Augustus Locke.

Born, 1888, Sutton, Ontario. 1910, B. S., School of Mining, Queen's Univ., Kingston, Ont. 1913, Ph.D., Yale Univ. 1906-09, Mining and geological work, German Development Co. of Canada. 1909-12, Mining geological work in eastern and western Canada for Geol. Survey of Canada.

Present position: Geologist, Secondary Enrichment Investigators.

**Franklin M. Bell**, Butte, Mont.

Proposed by George A. Packard, Charles W. Johnston, Samuel Barker, Jr.

Born, 1879, Cleveland, Ohio. 1897, High School graduate at Cleveland, Ohio; entered Case School of Applied Science. 1898, Enlisted Spanish American War. 1901, With Cananea Consolidated Copper Co., working in mines, concentrator and on engineering corps till 1904. 1904-05, Asst. Supt. at Sierra de Cobre Mine at Cananea. 1905, six months prospecting through district of Altar, Sonora, Mexico. 1905, six months at Yampa Smelter, Bingham, Utah. 1906, six months prospecting Montana. 1907, Cable Consolidated G. M. Co., assayer, engineer, etc. 1908-10, Asst. Supt. at Butte for Lewisohn Bros. 1911, with Butte Superior Copper Co.

Present position: Brokerage business, Butte, Mont.; Vice-President, Butte Chewelah Copper Co.

**James G. Berryhill**, Des Moines, Iowa.

Proposed by H. Foster Bain, Thomas T. Read, W. H. Aldridge.

Born, 1852, Iowa City, Iowa. B.Ph. and LL.B., State Univ. of Iowa. For past twenty years has been interested in mining and is now actively engaged therein.

Present position: Vice-President, Nevada-Douglas Copper Co.

**Alden Hugh Brown**, New York, N. Y.

Proposed by H. Foster Bain, Kirby Thomas, W. J. Loring.

Born, 1869, at Vinton, Iowa. 1891, State Univ. of Iowa, C. E. 1891-94, Asst. Engr., B. C. R. & N. Ry. 1894-98, Gen. Engr. work, Southern States. 1898-1904, Mgr., Wano Mine, Boulder Co., Colo.

Present position: 1904 to date, General mining engineering work.

Member of the Institute, 1903-07.



**Oscar Cartledge, Springfield, Ill.**

Proposed by H. H. Stoeck, F. W. De Wolf, R. Y. Williams.

Born, 1870, Shelbyville, Ill. 1878-94, Common and High Schools of Shelby county, Ill. During vacation periods and since have been employed in the mines. 1896-98, Mine Manager, New Virginia Coal Co., Johnston City, Ill. 1898-1900, Mine Manager, Johnston City Coal Co., Johnston City, Ill. 1900-08, Mine Supt. and Mining Engineer, Benton Coal Co., Benton, Ill. 1908-10, County Mine Inspector, Franklin, Ill. 1910-12, State Inspector of Mines, Illinois.

Present position : 1912 to date, Manager State Mine Rescue Stations, Illinois.

**John R. Curley, Leadville, Colo.**

Proposed by Thomas T. Read, D. W. Brunton, Charles J. Moore.

Born, 1843, Detroit, Mich. Public School education. 1872-78, Supt., Michigamme Iron Co., Marquette county, Mich. 1879, Supt., Sacramento Mining Co., Park county, Colo. 1884-87, Supt., Houghton Mining Co., Leadville, Colo. 1890, Supt., North Star & Salisbury Mining Co., Butte, Mont. 1897-99, Supt., Iron Silver Mining Co., Leadville, Colo.

Present position : State Mine Inspector, District No. 3, Leadville, Colo.

**Irving Annan Chapman, Brooklyn, N. Y.**

Proposed by George A. Packard, D. C. Bard, J. A. Grimes.

Born, 1890, Brooklyn, N. Y. 1913, E. M., Colorado School of Mines. Mar., 1913, Asst. to H. S. Munroe, examination of Ajax Mine, New Mexico.

Present position : July, 1913, to date, mucking at Tramway Mine, Anaconda Copper Mining Co., Butte, Mont.

**Arthur Brewster Clark, Butte, Mont.**

Proposed by George E. Moulthrop, Fred. T. Greene, B. H. Dunshee.

Born, 1872, Deer Lodge, Mont. 1891, Ogden Military Academy. 1893-1902, Mine Foreman and leasing mines in Butte district. 1902, Mgr. Ophir Copper Mining Co., Butte. 1903-10, President and Gen. Mgr. Paris Mining Co., Alma, Colo. 1912, Consulting Engineer for A. B. Wolvin.

Present position : Mining in Madison county, Mont.

**William L. Creden, Butte, Mont.**

Proposed by John D. Pope, D. C. Bard, L. T. Buell.

Born, 1869, Boston, Mass. 1886, Public Schools of Boston. 1890, Massachusetts Institute of Technology. 1890-95, Union Pacific Railway engineer. 1891, Miner in Butte. 1892-97, Engineer and Supt. for F. Aug. Heinze. 1897, Northern Pacific Railway engineer. 1911, examining and operating mines.

Present position : Consulting Engineer, Butte & Superior Copper Co.; Gen. Mgr. Davis-Daly Copper Co.; Consulting Engineer for A. B. Wolvin and W. G. Conrad.

**William Westaway Daw, Tavistock, Devon, England.**

Proposed by John W. Daw.

Born, 1882, London, England. Educated at King's College School, London. Spent four years, 1901-05, at the Camborne School of Mines and obtained the following certificates: Surveying, Dynamics, Hydrostatics, Assaying, Practical Geometry, Advanced Mining, Physics, Practical Chemistry, Vanning, Metallurgy, Trigonometry, Ore Dressing, Geology, Applied Mechanics, Technical Drawing. Been employed in Mexico as Asst. Mining Engineer. In Cornwall as Mine Manager. With the General Explorers as Gen. Mgr. and on inspection work.

Present position : Asst. Gen. Manager for the Ashanti Rivers & Concessions, Ltd., West Africa. London office, 7 Southampton Street, High Holborn, London, W. C.

**Frank T. Donahoe, Butte, Mont.**

Proposed by George E. Moulthrop, Reno H. Sales, C. W. Goodale.

Born, 1881, Ishpeming, Mich. 1904, Degree Engineer of Mines, Michigan College of Mines. 1899-1901, Surface laborer, hoisting engineer and timberman, Trimountain Mining Co. 1901-1904, Michigan College of Mines. 1904-05, Engineer for Sunday Lake & Brotherton Iron Mining Cos. 1905-06, Miner, Butte, Mont. 1906-10, Engineer with W. A. Clark.

Present position : 1910 to date, Mining Engineer, Original Mine, Anaconda Copper Mining Co., Butte, Mont.

**William Crawford Douglas, Plainfield, N. J.**

Proposed by J. A. Grimes, D. C. Bard, George A. Packard.

Born, 1889, New York, N. Y. 1911, E. M. Colorado School of Mines. 1911-12, Mining, Badger State Mine, Anaconda Copper Mining Co., Butte. Nov., 1912-April, 1913, Timber boss, Badger State Mine.

Present position: April, 1913, to date, Asst. Engineer, Steward Mine, Anaconda Copper Mining Co., Butte, Mont.

**Rear Admiral John R. Edwards, Washington, D. C.**

Proposed by William N. Best, C. F. Rand.

Born, 1853, Pottsville, Pa. 1871, Graduated, Pottsville, Pa., High School. 1874, Graduated, U. S. Naval Academy, Annapolis, Md. 1888-91, Professor Mechanical Engineering, University of South Carolina. While at the University pursued a law course and was admitted to practice before the Supreme Court of South Carolina. 1901-04, President, Naval Liquid Fuel Board. 1912, Chairman, American Delegation to London International Radio Conference. For forty years have made special study of mechanical and naval engineering matters. Have given special consideration to the general subject of liquid fuel, and the question of coal and iron production.

Present position: President of Board of Inspection for Shore Stations, Navy Department.

**Richard H. Ernest, Round Mountain, Nev.**

Proposed by J. F. McClelland, Thomas T. Read, J. F. Kemp.

Born, 1882, Denver, Colo. 1889-97, Public Schools. 1897-1901, West Denver High School. 1901-05, School of Mines, Columbia Univ., N. Y.; E. M. 1904-05, Practical mining, surveying, etc. 1905-06, Survey and geological examinations of oil properties in Oklahoma. 1906-07, Examination of properties in Goldfield district. Sampler and foreman, Oddie, Mohawk Lease, Goldfield. Supt. of three mining and leasing companies under control of T. L. Oddie. 1907-09, Assayer and Surveyor, Round Mountain Mining Co.; 1909-10, Asst. Supt.

Present position: 1910 to date, Gen. Supt., Round Mountain Mining Co. and Los Gazabo Milling Co.

**Arthur Feust, Santo Domingo, Nicaragua.**

Proposed by Thomas T. Read, Robert Peele, C. S. Herzig.

Born, 1890, New York, N. Y. 1894, Grad., N. Y. Public Schools. 1898, Grad., Horace Mann High School. 1898-1902, School of Mines, Columbia Univ.; E. M. 1902-04, Eng. Dept., B. & M. Cons. Copper and Silver Min. Co., Great Falls, Mont. 1904-05, Engineer, International Ore Treating Co., New York. 1905-07, Greene Gold & Silver Co., Chihuahua, Mexico. 1908-09, Manager, Standard Cons. Mining Co., Bodie, Cal. 1909-10, Manager, Quicksilver Mining Co., New Almaden, Cal.

Present position: 1911 to date, General practice in Nicaragua.

**Lester Daniel Frink, Butte, Mont.**

Proposed by L. T. Buell, John D. Pope, N. H. Emmona.

Born, 1882, Armona, Cal. 1904, Bachelor's degree, Stanford University. Elected Jan., 1906, member of A. I. M. E. Resigned Feb., 1909, in good standing.

Present position: 1905 to date, in the employ of North Butte Mining Co., as Mining Engineer.

**Robert Gordon, Montezuma, Costa Rica, C. A.**

Proposed by H. B. Price, P. G. Spilsbury, Robert S. Hanckel.

Born, 1879, Cornwall, N. Y. Class 1902, Syracuse University; Union College; Missouri State University. 1902-09, Engineering department of Mo. Pacific, Illinois Central, and Erie R. R. 1909, Engineer and Assayer, Montezuma Mines of Costa Rica. 1910-11, Engineer and Mine Supt., same mines.

Present position: Asst. Genl. Manager and Mine Supt., same mines.

**Albin K. P. Harmon, Jr., San Francisco, Cal.**

Proposed by W. C. Ralston, M. L. Requa, A. Burch.

Born, 1883, Oakland, Cal. 1903-07, College of Mining, University of California. 1907-08, Assay Department, U. S. Mint. 1908-10, Asst. Foreman, Ray Consolidated Copper Co., George O. Bradley. 1910, Concrete Foreman Great Western Power Co., J. A. Baumgarten. 1911-12, Asst. Geologist Union Oil Co. of California, W. W. Orcutt.

Present position: Mining Engineer and Geologist with office in San Francisco.

**James Hervey Herron, Cleveland, Ohio.**

Proposed by Carl F. Koehler, Mark A. Ammon, Robert R. Abbott.

Born, Girard, Pa., 1875. Prep. education, 1890, Girard Academy. 1909, University of Michigan, B. S. in M. E. 1890-94, Apprenticeship, Stearns Manufacturing Co., Erie, Pa. 1894-97, Draftsman, Asst. Chief and Chief Draftsman Erie City Iron Works, Erie, Pa. 1897-99, University of Michigan. 1899-1902, Draftsman and Asst. Engineer Cambria Steel Co., Johnstown, Pa. 1902-05, Chief Engineer. 1905-07, Commercial Manager Bury Compressor Co., Erie, Pa. 1907-09, Metallurgical Engineer, Detroit Steel Products Co., Detroit, Mich.

Present position: Consulting Metallurgical Engineer.

**Ezra A. Hewitt, Butte, Mont.**

Proposed by L. T. Buell, John D. Pope, N. H. Emmons.

Born, 1880, Waterloo, Iowa. 1904, four years at Hamline University, St. Paul, Minn., leading to Ph. B. No degree received. 1908, four years at University of Minnesota, receiving degree of E. M. 1909, with engineering department, Oliver Iron Mining Co., Gilbert, Minn. 1910, general mining work, Duluth & Toroda Mining Co., Bodie, Wash., also with Daly Reduction Co., Nickel Plate Mine, Hedley, B. C. 1911, general mining and cyanide milling, U. S. Smelting, Refining & Mining Co., Goldroad, Ariz. 1912, Asst. Engineer, G. N. Iron Ore Properties, Hibbing, Minn.

Present position: Geologist, North Butte Mining Co., Butte, Mont.

**Ross Browne Hoffman, Oakland, Cal.**

Proposed by Adolphe E. Borie, Spencer C. Browne, W. W. Mein.

Born, 1873, Oakland, Cal. 1891, Grad., Oakland High School. 1895, Grad., University of California, B. S. Post Grad. course in electrical and hydraulic engineering. 1895-1900, assisting Ross E. Browne and Charles F. Hoffman in mine examinations. 1900 to date, actively engaged in general mine examination work in Russia, Siberia, South America, Alaska, Mexico, United States, British Columbia. Employed by Guggenheim Exploration Co., London Exploration Co., Ltd., Pioneer Co. of Siberia, Ltd., John Hays Hammond, A. C. Beatty, R. D. Evans, Seeley W. Mudd, American Smelting & Refining Co., etc.

**Kenroku Ide, Kyoto, Japan.**

Proposed by E. P. Mathewson, Bradley Stoughton, Carl J. Tranerman.

Born, 1882, Nagano-ken, Japan. 1903-06, Studied at the Mining and Metallurgical Institute, Imperial University, Tokyo, Japan. 1906-10, Mining Engineer in Kosaka Copper Mine, Japan. 1910-11, studied mining machinery in the University of Tokyo. 1911-13, studied mining in general at the Technical High Schools, Aachen and Berlin, Germany.

Present position: Asst. Professor of Mining of the Imperial University, Kyoto, Japan.

**Clifton Beach Johnson, East Helena, Mont.**

Proposed by William Scallon, F. M. Smith, Alexander Leggat.

Born, 1878, Beloit, Wis. 1900, Beloit College. 1903, Michigan College of Mines, Degree Ph. B. and E. M. 1903, Asst. Engineer, Oliver Iron Mining Co., Ironwood. 1904, Cyanide Foreman, California Mine, Sumpter, Ore. 1905, mining in Eureka and Bingham, Utah. 1906-08, Chief Engineer of Construction Cia. Real del Monte y Pachuca and Blaisdell Syndicate. 1909-13, Draftsman and Engineer with Tennessee Copper Co. and A. S. & R. Co.

Present position: Engineer in charge of construction at East Helena.

**Oscar Lachmund, Greenwood, B. C.**

Proposed by D. W. Brunton, Edwin H. Platt, Frederic Keffer.

Born, 1866, St. Louis, Mo. 1887, Missouri School of Mines, Rolla, Mo., M. E. 1887-97, manual labor in mines and smelters. Assayer and Chemist at mines and sampling works in Colorado and Nevada. 1898-1900, Assayer, Guggenheim Refinery, Perth Amboy, N. J. 1901, Examining Engineer for Olancho Mining Co., Central America, now defunct. 1903-06, Superintendent, Reforma Mine, Mexico. 1906-08, Ore Buyer U. S. Smelting Co., Salt Lake City. 1908-12, professional practice.

Present position: Gen. Mgr., British Columbia Copper Co., Ltd.

**Eugene Hamilton Leslie, San Francisco, Cal.**

Proposed by Thomas T. Read, Robert Peele, Henry S. Munroe.

Born, 1884, Cadiz, O. Public Schools, Columbus, O. 1899-1902, Steele High School, Dayton, O. 1902-06, Princeton University, A. B. 1906-09, School of Mines, Columbia, E. M. 1909-13, Mining Engineering, and editor, *Mexican Mining Journal*.

Present position: Asst. editor, *Mining and Scientific Press*.

**Ivor Livingston, Petros, Tenn.**

Proposed by Charles E. Wait, Royal P. Jarvis, Walter H. Finley.

Born, 1878, Jasper, Tenn. 1894-1900, worked in mines of T. C. I. & R. R. Co. at Whitwell, Tenn. 1900-02, student University of Tennessee. 1902-03, Engineer, Campbell Coal & Coke Co., Orme, Tenn. 1903-05, student. University of Tennessee, B. S. 1905-07, engineer, Tenn. Cons. Coal Co., Tracy City, Tenn. 1907-09, Engineer, Campbell Coal & Coke Co. 1909-10, Supt of Mines, Coalmont, Ky. 1910-11, Supt. Mines, Davis Creek Coal Co. 1911-12, Supt. of Mines, Battle Creek Coal & Coke Co., Orme, Tenn.

Present position: Supt. of Mines, Bushy Mountain Coal Mines.

**Frederick MacCoy, El Oro, Mexico.**

Proposed by C. E. Rhodes, L. N. B. Bullock, K. F. Hoffmann.

Born, 1875, Indiana. 1893-94, Purdue Univ. 1894-96, private instructor, C. E. work. 1896-98, Transit man on mine surveys. 1898-1900, Transit man on railroad location work. 1905, appointed Civil Engineer on U. S. Reclamation Service (did not accept). 1908, accepted by Mexican Government as Civil Engineer; 1909, as Mining Engineer. 1900, Asst. Engineer, Dawson Fuel Co. 1902, Engineer, Raton Coal & Coke Co. 1905, Engineer, Coal Dept., Santa Fe R. & E. Ry. 1906, Division Engineer, Mexican Central Ry. 1908, Asst. Engineer, Guanajuato Development Co. 1909, Chief Engineer, Esperanza Mining Co.

Present position: Asst. Manager, Esperanza Mining Co.

**Philip M. McHugh, Denver, Colo.**

Proposed by John V. N. Dorr, Charles A. Chase, Louis Cohen.

Born, 1887, Hastings, Minn. 1901-05, High School, Aberdeen, S. D. 1907-11, Colorado School of Mines, Degree E. M. 1906-07, Assayer, Surface foreman, Cobalt Central Mining Co., Cobalt, Ont. 1909, Millman, United Mines Corporation, Tuolumne, Cal. 1910, Surveyor, Great Northern Irrigation & Power Co., Routt county, Colo. 1911, Metallurgical work, Granite Bi-Metallic Mining Co., Phillipsburg, Mont.

Present position: 1911 to date, Engineer, Dorr Cyanide Machinery Co.

**Vachel Harry McNutt, Tulsa, Okla.**

Proposed by C. R. Forbes, G. H. Cox, H. H. Buehler.

Born, 1888, Minerva, Ky. 1902-06, High School, Monroe City, Mo. 1906-10, Student, Mo. School of Mines, Rolla, Mo.; B. S. in E. M. 1910-12, P. G., Mo. School of Mines; M. S. 1909-11, summer months, field work in geology, Mo. Bureau of Mines, H. H. Buehler, State Geologist. 1910-13, winter months, instructor of geology and mineralogy, Mo. School of Mines, Rolla. 1913, summer months, examining geologist, Powder & Pomeroy, Oil Producers, Tulsa, Okla.

Present position: Member of firm Valerius & McNutt, Geologists and Mining Engineers, Tulsa, Okla.

**Donald Gazlay Miller, Bisbee, Ariz.**

Proposed by Walter Douglas, Gerald Sherman, Arthur Notman.

Born, 1888, Sandusky, Ohio. 1905, Grad., Irving High School, New York. 1905-09, Columbia Univ.; E. M. 1909-10, Engineering staff, Moctezuma Copper Co. 1910-11, Mining Engineer; 1911, Asst. Supt.; 1912, Supt., Transvaal Copper Mining Co., Cumpas, Mexico.

Present position: 1912 to date, Mining Engineer, Phelps, Dodge & Co.

**Edward Hale Perry, Boston, Mass.**

Proposed by L. C. Graton, Reno H. Sales, Augustus Locke.

Born, 1887, Boston, Mass. 1906-13, Harvard Univ.; B. S. and E. M. 1911, summer, Assayer, Copper Queen Cons. Mining Co. 1912, Timberman and member, Geol. Dept., Detroit Copper Co.

Present position: Geologist, Secondary Enrichment Investigation.

**Frederic Emory Pierce, New York, N. Y.**

Proposed by J. A. Van Mater, Lewis G. Lowand, William A. Pomeroy.

Born, 1870, Flemington, N. J. 1888-92, Columbia Univ.; C. E. 1892-94, Draftsman, N. J. Steel & Iron Co. 1894-95, Rodman, P. R. R. 1895-98, Asst. to Engineer, Wallabout Improvement, Brooklyn Dept. City Works. 1898-1900, Drafting and engineering work for N. J. Zinc Co. 1900-04, Asst. Supt.; 1904-06, Asst. to Chief Engineer; 1906-09, Engineer of Construction; 1909-12, Chief of Construction.

Present position: 1912 to date, Chief Engineer, N. J. Zinc Co.

Royden Campbell Philpott, Guayaquil, Ecuador, S. A.

Proposed by T. W. Mather, A. L. Kelly, J. W. Mercer.

Born, 1883, Iona, Ont., Canada. 1890-98, Public schools, Ridgeway, Ont., Canada. 1898-1901, High School, Cripple Creek, Colo. 1902-04, Colorado School of Mines. 1904-06, Miner on Findley Mine, Cripple Creek, Colo. 1906-07, Ely, Nev., with Nevada Northern R. R. 1907-10, With Crosby & Atherton, Mining Engineers, Cripple Creek, Colo.

Present position: 1911 to date, General foreman, The South American Development Co., Santa Rosa; Road Construction.

C. Herbert Poirier, New York, N. Y.

Proposed by Fred. J. Pope, Russell T. Cornell, G. M. Colvocoresses.

Born, 1877, Duluth, Minn. 1898-99, Mill Foreman, Four Hills Mining Co., Sierra county, Cal. 1900-01, Mine Supt., Lucky Bug Mining Co., Idaho City, Idaho. 1902-03, Mine Supt., Harvard Mining Co., Tuolumne county, Cal. 1904-06, Mgr., Goldfield Frances Mining Co., Goldfield, Nev. 1907-09, Consulting Engineer, Eastern Exploration Co., Boston, Mass.

Present position: 1910 to date, Consulting Engineer, Genl. Mgr. Porcupine Gold Mines Co., Schumacher, Ont., Canada.

Edwin Jay Prindle, New York, N. Y.

Proposed by F. L. Grammer, Charles Dorrance, Jr., W. G. Whildin.

Born, 1868, Washington, D. C. 1890, Lehigh Univ.; M. E. 1893, National Univ., Washington, D. C. Bachelor of Laws; 1894, Master of Laws. 1890-99, Examiner, U. S. Patent Office. 1899-1910, Mechanical engineering experience, resulting in election to full membership in American Society of Mechanical Engineers. 1899 to date, Practice of patent law. 1908, elected member American Electrochemical Society.

Present position: Patent Lawyer.

John Edward Rea, Spokane, Wash.

Proposed by J. C. Haas, L. K. Armstrong, Francis A. Thomson.

Born, 1883, Muskegon, Mich. 1904, Grad., Michigan College of Mines. 1909-10, Post Grad. course in copper mining at Washington State College. 1905-08, Asst. Engr., Spokane Intl. Ry. 1908, Member of firm, Haas & Rea. 1908, Min. Engr. and foreman, Spokane Lead Mine, Metaline, Wash. 1909, Engr., Copper River & Northwestern Ry, Alaska. 1910, Prospecting and locating claims, Nevada. 1911-12, Engr., C. H. Green Co., Spokane. 1913, Sampling and reporting on mines in Northwest for J. Gordon Hardy.

Present position: Mining Engineer, Gold Dust Mining Co., Seward, Alaska.

Charles Henry Schmalz, Great Falls, Mont.

Proposed by C. W. Goodale, J. H. Klepinger, Milo W. Krejci.

Born, 1875, Chicago, Ill. 1897, Gates Iron Works, Chicago, Ill.; Research Laboratory. 1898-1901, Colorado School of Mines, Golden, Colo. 1901, Case School of Applied Science, Cleveland, Ohio. 1903, Barth Elevator Co., Milwaukee, Wis.; Supt. 1904, Cananea Consolidated Copper Co., Cananea, Mexico; Asst. M. M. 1906-09, Great Falls Iron Works, Great Falls; Manager.

Present position: 1909 to date, Asst. Master Mechanic, Anaconda Copper Mining Co., Great Falls, Mont.

Leonard Durant Sivyver, Los Angeles, Cal.

Proposed by Frank Robbins, Theodore B. Comstock, F. J. H. Merrill.

Born, 1853, Milwaukee, Wis. 1865-70, Student at Milwaukee Academy. 1869-70, Student of mineralogy and geology. 1870-72, Practiced in field of Kansas, Missouri, and Arizona. 1873-74, With the Sunnyside Mining Co., of Boulder county, Colo. 1875-92, Exploring, operating mines, etc., Arizona, Kansas, Colorado, Washington, Idaho, British Columbia. 1892-93, Chief of Mines, Mining, and Mineral Exhibits for the State of Washington, World's Columbian Exposition. 1893 to date, Mining practice.

Present position: Examining and reporting on Mines and Geological features.

Horatio L. Small, Rio de Janeiro, Brazil.

Proposed by J. C. Branner, H. W. Young, D. M. Folsom.

Born, 1884, Muscatine, Iowa. 1911, Leland Stanford Univ.; A. B. 1906, General underground work, Havilla Mine, Nashville, Cal. 1907, General underground work, River Mill Mine, Placerville, Cal. 1909, Underground work, Melones Mine, Cal. 1911, Geol., Cal. State Highway Commission, Sacramento.

Present position: Geologist, Inspectoria de Abros Contra as Seccas (Brazilian Reclamation Service).

**Ralph Hamilton Soper, Bahia, Brazil.**

Proposed by J. C. Branner, H. W. Young, D. M. Folsom.

Born, 1889, Menlo Park, Cal. 1909-11, Leland Stanford, Jr., Univ. 1907-08, Surveyor, Cal. Development Co. 1910, In concentrator, Nevada Cons. Copper Co. 1911. Topographic geology in Venezuela Oil Field for Barber Asphalt Co.

Present position : 1912 to date, Geologist, Inspectoria de Abros Contra as Seccas.

**C. J. Stone, Butte, Mont.**

Proposed by Oscar Rohn, Fred T. Greene, J. C. Febles, George E. Moulthrop.

**Thomas Thorkildsen, Los Angeles, Cal.**

Proposed by C. Colcock Jones, Frank A. Keith, S. W. Mudd.

Born, 1872, Wisconsin. Operations chiefly non-metallics.

Present position : President and Treasurer Sterling Borax Co.

**John Hamilton Troutman, Denver, Colo.**

Proposed by J. A. Van Mater, William A. Pomeroy, A. D. Beers.

Born, 1856, Philadelphia, Pa. 1881-97, Lehigh Zinc & Iron Co. 1897 to date, N. J. Zinc Co. and associate companies. Closely associated with the mining, manufacturing, and business management of the above companies.

Present position : Gen. Mgr., Empire Zinc Co.

**Ernest Eugene Watson, Butte, Mont.**

Proposed by L. T. Buell, John D. Pope, N. H. Emmons.

Born, 1887, Park City, Utah. 1907-11, B. S. in Mining, University of Utah.

Present position : 1911 to date, Asst. Engineer, North Butte Mining Co.

**Alfred Hurst Weaver, Santiago de Cuba, Cuba.**

Proposed by George W. Pfeiffer, Edward H. Emerson, Charles F. Rand.

Born, 1889, Norristown, Pa. Public and High Schools of Norristown, Pa. 1903-07, college preparatory course. 1907-08, Mfg. Dept., United Gas Improvement Co., Waterbury, Conn. 1908-10, with George W. Weaver, Sewer, Paving and General Contractor, Norristown, Pa. 1910-12, with S. C. Corson, Borough Engineer, Norristown.

Present position : With Spanish-American Iron Co., Daquiri, Cuba.

**Horace E. Williams, Rio de Janeiro, Brazil.**

Proposed by J. C. Branner, A. H. Purdue, N. F. Drake.

Born, 1866, Arkansas. Grad., Univ. of Arkansas and Stanford Univ. in Geology. Some years assistant on Geol. Survey of Arkansas. Several years chief topographer, Geol. Survey, S. Paulo, Brazil. Author, Map of State of S. Paulo, Brazil; Book on Secular Variation and the Distribution of Magnetic Declination in Brazil, 1913; Book on the Determination of Azimuth by Observation of the South Polar Star, Sigma Octaxti, 1912.

Present position : Asst. Geologist and Chief Topographer, Servico Geologico de Brazil.

**Rollo D. Winne, Crystal Falls, Mich.**

Proposed by W. E. Hopper, Thomas T. Read, F. W. Sperr.

Born, 1889, Adrian, Mich. 1903-07, Adrian High School. 1908-11, Michigan College of Mines; B. S. and E. M. 1911, Engineer, Iron County Road Commission. 1912, Engineer and Pit Foreman, Verona Mining Co., Palatka, Mich. 1913, Deputy Mine Inspector, Crystal Falls, Mich.

Present position : Deputy County Mine Inspector.

**Augustus B. Wolvin, Butte, Mont.**

Proposed by Samuel Barker, Jr., B. H. Dunshee, John Gillie.

Born, 1857, Cleveland, Ohio. 1901-04, with U. S. Steel Corporation. 1904-07, Zenith Furnace Co. 1907-13, President Butte Superior Copper Co.

Present position : President Butte Duluth Mining Co.

**Harold William Kennett Wood, Sydney, Australia.**

Proposed by John Moffat, James R. M. Robertson, Fred. D. Power.

Born, 1889, Sydney, N. S. W. 1894-1901, Stanmore S. P. School. 1901-04, Fort Street High School. 1904-07, Sydney Technical College (Chemistry). 1904-07, Asst. to late Dr. A. Helms. 1907-09, Asst. chemist to E. Janetzky.

Present position : 1909 to date, Managing chemist and manager for Charles F. G. Kopsch & Co., Analysts and Assayers.

#### *Associates.*

**Frank Clinton Bailey, Spokane, Wash.**

Proposed by L. K. Armstrong, J. C. Haas, Richard S. McCaffery.

Born, 1855, Janesville, Wis. Educated at common schools, Janesville. 1893 to date, mining operator, Greenwood, B. C.; Newport, Wash.; Wallace, Idaho; Chewelah, Wash.

James C. H. Ferguson, San Francisco, Cal.

Proposed by Edward H. Benjamin, E. P. Mathewson, Frederick Laist.

Born, 1867, Holland. Educated in Europe. 1895, University of California, mining course. 1895-1901, Union Iron Works, S. F.

Present position: 1901 to date, Pacific Coast Sales Agent, Midvale Steel Co., Philadelphia.

Arthur Smith, Ely, Nevada.

Proposed by Alfred B. Colwell, Charles F. Rand, C. B. Lakenan.

Born, 1866, Oxfordshire, England. Public school education. 1884, worked in Nelson Mine, Mich. 1884-96, worked in various mines in Butte, principally Anaconda Mine of the A. C. M. Co., and Mountain View Mine of the B. & M. Co., as ordinary miner. 1896-1907, more or less connected with mining properties. 1909 to date, Agent and manager of Coppermines Co.

Present position: President, Copper National Bank, Ely, Nev.; McGill National Bank, McGill, Nev.

Herbert DeQuincy Taylor, Wilmington, Del.

Proposed by Louis D. Huntoon, E. Gybbon Spilsbury, G. M. Colvocoresses.

Born, 1865, St. Louis, Mo. 1881-83, Manual Training School. 1883-86, Washington University, St. Louis. 1892-1913, with DuPont Powder Co. handling explosives as a sales agent and a branch office manager. 1913, Atlas Powder Co., in charge of Joplin lead and zinc district and contractors' division. 1892-1913, E. I. DuPont de Nemours & Co. and Atlas Powder Co., Wilmington, Del.

Present position: Atlas Powder Co. in charge of contractors' division.

#### CHANGES OF ADDRESS OF MEMBERS.

The following changes of address of members have been received at the Secretary's office during the months of July and August, 1913. This list, together with the lists published in *Bulletin* Nos. 76 to 79, April to July, 1913, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Mar. 1, 1913, and brings it up to the date of Sept. 1, 1913.

|                                                                                         |                                                                       |
|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| ABADIE, EMILE R.                                                                        | Mutual Savings Bank Bldg., San Francisco, Cal.                        |
| ADAMS, ARTHUR K.                                                                        | Socorro, N. M.                                                        |
| ANDERSON, ALEXANDER                                                                     | Bella Vista 22, Minas de Rio Tinto, Prov. Huelva, Spain.              |
| ANDERSON, J. K.                                                                         | 1414 Virginia St., Charleston, W. Va.                                 |
| AVERY, JOHN, Engr.                                                                      | Amalgamated Zinc (DeBavay's), Ltd., Broken Hill, N. S. W., Australia. |
| BACKUS, GEORGE S.                                                                       | Care Leonard Hotel, Butte, Mont.                                      |
| BAIRD, DUDLEY.                                                                          | 2624 Bancroft Way, Berkeley, Cal.                                     |
| BAKER, DAVID.                                                                           | Ingall St., Mayfield, Newcastle, N. S. W., Australia.                 |
| BARNES, W. A.                                                                           | Utah Metal Mining Co., Bingham Canyon, Utah.                          |
| BATCHELLER, JAMES H.                                                                    | Mizpah Hotel, Tonopah, Nev.                                           |
| BEHR, HANS C.                                                                           | 233 Broadway, New York, N. Y.                                         |
| BERGEN, RAYMOND C.                                                                      | P. O. Box 335, Hightstown, N. J.                                      |
| BIRKINBINE, J. L. W.                                                                    | Benson Mines, St. Lawrence Co., N. Y.                                 |
| BISHOP, ROY N.                                                                          | Crocker Bldg., San Francisco, Cal.                                    |
| BLAIR, ALLEN F.                                                                         | 318 1st S. St., Seattle, Wash.                                        |
| BOLLES, M. N.                                                                           | Conner Hotel, Joplin, Mo.                                             |
| BONE, ALBERT J., Smelter Supt., Granby Cons. Mining, Smelting & Power Co.,              | Anxox, B. C., Canada.                                                 |
| BOOTH, HARRY M.                                                                         | Clark, Routt Co., Colo.                                               |
| BORDEAUX, A. F. J.                                                                      | S. Real par S. Pierre d'Albigny, Savoie, France.                      |
| BOROWSKY, A. G., Secy., Penna. Rivet Mfg. Co., 11th and Cambria Sts., Philadelphia, Pa. |                                                                       |
| BOSVIAT, HENRY                                                                          | Mesves-Sur-Loire, Nievre, France.                                     |
| BOURDARIAT, A. J.                                                                       | Villa Fugier, Coublevie par Voiron, Isère, France.                    |
| BOYD, A. W.                                                                             | S. 519 Madison St., Spokane, Wash.                                    |
| BRADLEY, D. H., JR.                                                                     | 1700 Rampart St., Spokane, Wash.                                      |
| BRETHERTON, W. L.                                                                       | Mgr., Clarkdale Improvement Co., Clarkdale, Ariz.                     |
| BRINSMAD, R. B.                                                                         | Ueson Angel 5, Puebla, Pue., Mexico.                                  |
| BROOKS, RAYMOND, Min. Engr.                                                             | 3031 Prairie Ave., Chicago, Ill.                                      |
| BROWN, W. SINCLAIR                                                                      | Lebong Donok, Benkoelen, Sumatra, D. E. I.                            |
| BUELL, L. T.                                                                            | P. O. Box 1607, Butte, Mont.                                          |
| CHAMBERLAIN, JOHN R., Supt. of Transportation, El Aguila Oil Co.,                       |                                                                       |
|                                                                                         | Apartado 150, Tampico, Tamps., Mexico.                                |
| COCKERELL, L. M.                                                                        | Isthmian Club, Piccadilly, London, W., England.                       |

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|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| CORNELL, ROY L. G.                                                                        | 299 Mission St., Santa Cruz, Cal.                               |
| DE HORA, MANUEL H., Cons. Min. and Civ. Engr.,                                            | Care Catlin, Powell & Co., 15 Broad St., New York, N. Y.        |
| DEL MAR, ALGERNON                                                                         | South Pasadena, Cal.                                            |
| DRESSER, CLARENCE G.                                                                      | Care Inspiration Cons. Copper Co., Miami, Ariz.                 |
| DRUMMOND, T. R.                                                                           | 1780 El Cerrito Pl., Hollywood, Cal.                            |
| EARLING, ROY B., Supt. Metcalf Group.                                                     | Arizona Copper Co., Ltd., Metcalf, Ariz.                        |
| EGGERS, JOHN H., JR.                                                                      | Rochester Mines Co., Upper Rochester, Nev.                      |
| ELGUERA, MANUEL                                                                           | 1746 P St., Washington, D. C.                                   |
| ELSING, MORRIS J., Min. Engr. and Geol., Cananea Cons. Copper Co., Cananea, Son., Mexico. |                                                                 |
| EMLAW, HARLAN S.                                                                          | 139 Herkimer St., Brooklyn, N. Y.                               |
| ENGELHARDT, E. C.                                                                         | Garfield Smelting Co., Garfield, Utah                           |
| ESHELMAN, S. K., JR., Steel Engr.                                                         | Columbia Steel & Shifting Co., Pittsburg, Pa.                   |
| E. L. ESTERBROOK                                                                          | Platteville, Wis.                                               |
| EVANS, GEORGE W.                                                                          | 1011 N. 47th St., Seattle, Wash.                                |
| EYE, CLYDE M., Supt.                                                                      | American Girl Mine, Ogilby, Cal.                                |
| FABBAR, B. L.                                                                             | 1127 Montana St., El Paso, Texas.                               |
| FAWCETT, JAMES H.                                                                         | Athenæum Club, Sydney, N. S. W., Australia.                     |
| FEGRÆUS, TOBERN.                                                                          | Nobel Brothers, St. Petersburg, Russia.                         |
| FOSTER, D. F., Broomassiss Gold Mines, Ltd., Broomassiss, Gold Coast Colony, West Africa. |                                                                 |
| GAHL, RUDOLF, Met.                                                                        | P. O. Box 1191, Clifton, Ariz.                                  |
| GAMBRIEL, G. T., JR.                                                                      | 1706 14th Ave., S., Birmingham, Ala.                            |
| GERHARDT, R. B.                                                                           | 604 C St., Sparrows Point, Md.                                  |
| GOODRICH, R. R.                                                                           | Columbia University, New York, N. Y.                            |
| GREENSFELDER, NELSON S.                                                                   | 809 Paulsen Bldg., Spokane, Wash.                               |
| GUERNSEY, FORBES W.                                                                       | Mason Valley Smelter, Thompson, Nev.                            |
| HAAHIS, D. D.                                                                             | Federal Bldg., Fall River, Mass.                                |
| HALL, GEORGE                                                                              | Mina da Serra da Caveira, Grandola, Portugal.                   |
| HARDMAN, JOHN E.                                                                          | 601 Royal Trust Bldg., Montreal, Canada.                        |
| HARRIS, ARTHUR L.                                                                         | Dillsboro, Jackson Co., N. C.                                   |
| HAWLEY, ROBERT H., Asst. Supt.                                                            | Magna Plant, Utah Copper Co., Garfield, Utah.                   |
| HENDERSON, J. A. L.                                                                       | Worcester House, 7 Walbrook, London, E. C., England.            |
| HILL, CHARLES R.                                                                          | Care F. H. Platt, 2 Rector St., New York, N. Y.                 |
| HODGES, A. B. W., Min. and Met. Engr.                                                     | 109 S. Kingsley Drive, Los Angeles, Cal.                        |
| HOLDEN, JAMES O. E.                                                                       | Newcastle Coal Co., Ltd., Drumheller, Alta, Canada.             |
| HORE, REGINALD E., Editor, <i>The Canadian Mining Journal</i> , 44-46 Lombard St.,        |                                                                 |
|                                                                                           | Toronto, Ont., Canada.                                          |
| HOWER, CHARLES L.                                                                         | 738 Franklin St., Johnstown, Pa.                                |
| HUANG, SAOSAN KEN                                                                         | Tayeh Iron Mines, Tayeh, Hupeh, China.                          |
| HUDSON, A. W.                                                                             | P. O. Box 436, Butte, Mont.                                     |
| HUSTON, HARRY L., Min. Engr.                                                              | 708 Mills Bldg., San Francisco, Cal.                            |
| IRELAND, JAMES D.                                                                         | 705 Fidelity Bldg., Duluth, Minn.                               |
| IRWIN, DAVID D.                                                                           | Morenci, Ariz.                                                  |
| JACKSON, WALTER H., Engr.                                                                 | Golconda Northern Ry., Golconda, Ill.                           |
| JENKS, ARTHUR W., Care H. C. Pemberton, 275 Calle Alvear, Jujuy,                          |                                                                 |
|                                                                                           | Argentine Republic, So. America.                                |
| JOHNS, J. HARRY                                                                           | Thorsden, Guildford Rd., Woking, England.                       |
| JOHNSON, J. E., JR., Cons. Engr. and Met.                                                 | 52 William St., New York, N. Y.                                 |
| JONES, OWEN, 50 Addison Mansions, Blythe Rd., W. Kensington, London, W., England.         |                                                                 |
| KEENEY, ROBERT M.                                                                         | Box 393, Oakmont, Pa.                                           |
| KELLOGG, RALPH M.                                                                         | P. O. Box 172, Elko, Nev.                                       |
| KELLY, EDWARD                                                                             | Dover, N. J.                                                    |
| KENYON, PERCY                                                                             | Brookfield, Currier Lane, Ashton-under-Lyne, England.           |
| KILBOURN, WILLIAM D., Met. of Lead Dept.                                                  | International S. & R. Co., Tooele, Utah.                        |
| KINNEY, H. D.                                                                             | Utah Metal Mining Co., Bingham Canyon, Utah.                    |
| KNAPP, S. A., Res. Dir., American Potash, Inc.,                                           |                                                                 |
|                                                                                           | 1111 Merchants Natl. Bank Bldg., San Francisco, Cal.            |
| KOEHLER, WILLIAM                                                                          | E. 792 Lakeview Rd., N. E., Cleveland, Ohio.                    |
| KURYLA, M. H., Rep. Merrill Metallurgical Co.,                                            |                                                                 |
|                                                                                           | 34 Edificio del Banco de Londres y Mexico, Mexico City, Mexico. |
| LADD, G. E., Prest. of New Mexico College of Agriculture and Mechanic Arts,               |                                                                 |
|                                                                                           | State College, N. M.                                            |
| LANCASTER, HENRY M.                                                                       | Care Genl. Delivery, Cœur d'Alène, Idaho.                       |
| LANGTON, JOHN, Cons. Engr.                                                                | 233 Broadway, New York, N. Y.                                   |
| LAUDIG, O. O.                                                                             | 500 Maple St., Battle Creek, Mich.                              |
| LAVERY, V. M.                                                                             | 418 McCormick Bldg., Chicago, Ill.                              |



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|--------------------------------------------------------------------------------------------|------------------------------------------------------------------|
| LELAND, EVERARD, Geol.....                                                                 | Shannon Copper Co., Metcalf, Ariz.                               |
| LINCOLN, FRANCIS C., Res. Engr., Bolivian Dev. & Exploitation Co., La Paz, Bolivia, S. Am. |                                                                  |
| LINDSAY, JOHN A. M., B. H. P. Co., Steel Wks.....                                          | Newcastle. N. S. W., Australia.                                  |
| LONSBERRY, GEORGE A.....                                                                   | Care First National Bank, Nogales, Ariz.                         |
| MCCART, ROBERT, JR.....                                                                    | 202 Main St., Fort Worth, Tex.                                   |
| MCGRATH, JOHN.....                                                                         | Mexico Mines of El Oro, El Oro, Mex., Mexico.                    |
| McKEE, J. A.....                                                                           | 69 South Root St., Aurora, Ill.                                  |
| MCLEOD, HOWARD D.....                                                                      | 1927 45th Ave., S. W., Seattle, Wash.                            |
| MACDONALD, M. E., Zacatecas Min. & Met. Co.....                                            | 35 Wall St., New York, N. Y.                                     |
| MAKITA, TAMAKI.....                                                                        | 43 Kitahigakubocho, Asabuku, Tokyo, Japan.                       |
| MARRIOTT, F. A.....                                                                        | Care Willoughby's Cons., Ltd., Bulawayo, Rhodesia, So. Africa.   |
| MAY, JESSE J.....                                                                          | 130 N. 4th St., Mt. Vernon, N. Y.                                |
| MEGRAW, H. A., <i>Engrg. and Min. Journal</i> .....                                        | 505 Pearl St., New York, N. Y.                                   |
| MENTZEL, CHARLES.....                                                                      | 29 Broadway, New York, N. Y.                                     |
| MOONEY, J. D., Sales Manager, The B. F. Goodrich Co.....                                   | Akron, Ohio.                                                     |
| MORRISON, HAROLD A., Globe Cons. Mining Co.....                                            | Dedrich, Trinity Co., Cal.                                       |
| MURPHY, EDWARD M.....                                                                      | 166 Huntington Ave., Boston, Mass.                               |
| NICHOLS, HORACE G., Bainbridge, Seymour & Co., 353 Salisbury House, London, E. C., Eng.    |                                                                  |
| OSBORNE, CHARLES G.....                                                                    | Care Consumers Co., State & Quincy Sta., Chicago, Ill.           |
| OSGOOD, SAMUEL W.....                                                                      | 4810 St. Lawrence Ave., Chicago, Ill.                            |
| PARKER, J. L.....                                                                          | Burmia, Alta., Canada.                                           |
| PATRICK, WILLIAM B.....                                                                    | 923 First National Bank Bldg., Denver, Colo.                     |
| PORTUGAL, J. H.....                                                                        | Corey Apts., East So. Temple St., Salt Lake City, Utah.          |
| POSTLETHWAITE, R. H.....                                                                   | Farms Finance Co., 865 Monadnock Bldg., San Francisco, Cal.      |
| POWER, HAROLD T.....                                                                       | 1009 Merchants Exchange Bldg., San Francisco, Cal.               |
| RAKOWSKY, VICTOR.....                                                                      | Miami, Okla.                                                     |
| RANDOLPH, B. S.....                                                                        | Tonoloway Quarries, Tonoloway, via Hancock, Md.                  |
| REECE, F. B.....                                                                           | Inspiration Cons. Copper Co., Miami, Ariz.                       |
| REINHARDT, G. A., Met.....                                                                 | Youngstown Sheet & Tube Co., Youngstown, Ohio.                   |
| RHODES, WILLIAM B.....                                                                     | Care L. A. Rhodes, Golden, Colo.                                 |
| RICE, JOHN A.....                                                                          | Drawer 994, Haileybury, Ont., Canada.                            |
| RICKARD, HAROLD, Care Southern Shan States Synd. (1909), Ltd., Kalaw,                      |                                                                  |
|                                                                                            | Southern Shan States, Burma, India.                              |
| ROBBINS, FRANK.....                                                                        | 1400 Hibernian Bldg., Los Angeles, Cal.                          |
| RODGERS, J. H.....                                                                         | 2338 10th Ave. N., Seattle, Wash.                                |
| ROSE, EDWARD P.....                                                                        | 109 W. Unaka Ave., Johnson City, Tenn.                           |
| SANDERS, W. E.....                                                                         | Sonora, Cal.                                                     |
| SCARBOROUGH, F. W., Cons. Engr.....                                                        | Traveler's Bldg., Richmond, Va.                                  |
| SCHNEIDER, GEORGE W.....                                                                   | 1730 Logan St., Denver, Colo.                                    |
| SHALLCROSS, VINCENT F., St. George's House, 117 St. George's Terrace, Perth, W. Aust.      |                                                                  |
| SMITH, H. DEWITT.....                                                                      | Santo Domingo City, Santo Domingo, W. I.                         |
| SMYKER, ALFRED E.....                                                                      | Canal Dover, Ohio.                                               |
| STEPHEN, A. E.....                                                                         | 63 Castlereagh St., Sydney, N. S. W., Australia.                 |
| THOMAS, W. F. A.....                                                                       | 8 Victoria Ave., Bishopsgate St., London, E. C., England.        |
| THOMAS, DAVID R.....                                                                       | Care W. R. Cox, 165 Broadway, New York, N. Y.                    |
| THOMAS, GEORGE S.....                                                                      | 728 W. Granite St., Butte, Mont.                                 |
| THOMAS, MARION L.....                                                                      | 112 College St., Alliance, Ohio.                                 |
| THOMPSON, CHARLES D.....                                                                   | Honesdale, Pa.                                                   |
| TOLMAN, C. F., JR.....                                                                     | Leland Stanford, Junior, University, Stanford Univ., Cal.        |
| TRAUTMAN, CARL J.....                                                                      | 832 Colorado St., Butte, Mont.                                   |
| TUTTLE, ARTHUR L.....                                                                      | 119 Taylor St., San Antonio, Texas.                              |
| WAGNER, PERCY A., Min. Engr. and Geol.....                                                 | P. O. Box 1277, Pretoria, South Africa.                          |
| WALLACE, ROBERT.....                                                                       | Lovelock, Nevada.                                                |
| WARD, ERNEST E.....                                                                        | Care L. D. Smith, R. F. D. 1, Colfax, Wash.                      |
| WASHBURN, C. W.....                                                                        | U. S. Geological Survey, Washington, D. C.                       |
| WAYNE, FREDERICK S.....                                                                    | 1507 Otis Bldg., Chicago, Ill.                                   |
| WEED, WALTER HARVEY.....                                                                   | Houghton, Mich.                                                  |
| WEIGALL, HENRY S., Mgr.....                                                                | Chosen Gold Mines, Ltd., Care F. A. Oldis, Seoul, Korea.         |
| WELLS, JAMES S. C.....                                                                     | Canon City, Colorado.                                            |
| WHITTIER, C. C.....                                                                        | R. W. Hunt & Co., 808 McArthur Bldg., Winnipeg, Man., Canada.    |
| WILDING, JAMES, JR.....                                                                    | 1009 Union St., Alameda, Cal.                                    |
| WILKINS, WILLIAM, Mgr.....                                                                 | Lake Superior Iron & Chemical Co., Ashland, Wis.                 |
| WILLIAMS, E. H.....                                                                        | Care Beachland Gas Co., Cleveland, O.                            |
| WILMOT, H. CLIFFORD, Mgr.....                                                              | Syndicate Mining Co., Arroyo, Masbate, P. I.                     |
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| Date of Election. | Name.                  | Date of Death.   |
|-------------------|------------------------|------------------|
| 1899.             | **Gage, Eliphulet B.,  | April 12, 1913.  |
| 1886.             | *Holden, L. E.,        | August 26, 1913. |
| 1906.             | *Kaeding, Henry B.,    | .....            |
| 1905.             | *Kennedy, Neil,        | June 8, 1913.    |
| 1893.             | *Kennedy, Orran W.,    | June 8, 1913.    |
| 1904.             | *Snyder, Baird,        | July 9, 1913.    |
| 1893.             | **Treadwell, Edwin D., | .....            |

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DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Butte meeting, Aug. 18 to 21, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1913, when Vol. XLVI. of the *Transactions* will go to press. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## Rock-Drilling Economics.

BY W. L. SAUNDERS, NEW YORK, N. Y.

(Butte Meeting, August, 1913.)

### IMPORTANCE OF ROCK DRILLING.

It has been estimated that the value of the mineral products of the United States is about \$2,000,000,000 a year; that about \$25,000,000 is expended annually for explosives and that about double this sum is paid in wages where blasting is done. The value of the mineral products does not adequately express the importance of the industry involved in the excavation of rock and ore because of the enormous sums of money expended in tunnel driving, in quarries, and in open-cut excavation generally. We know that the Catskill Aqueduct in the neighborhood of New York, which is now nearing completion, has cost some \$165,000,000 and that about one-third of this may be rated as rock excavation. These illustrations are given in order to call attention to the great importance of an industry the extension and development of which in our industrial life depend so much upon the economics of rock drilling.

Reference has been made to the new Catskill Aqueduct. There are three aqueducts leading into New York, each built at periods separated by some 20 years of time. The first one, known as the Old Aqueduct, conveys the waters of the Croton river to New York City in a manner which reminds one of the old Roman aqueducts, the ruins of which are still in evidence. The engineers who laid out these old conduits sought to direct their lines around the hills and into the valleys, at all times avoiding the rock. When it was necessary to cross a river or a deep ravine, a bridge or causeway was constructed. High Bridge, over the Harlem river, is an arched masonry viaduct differing in no essential features from the aqueducts of the Romans. When the second Croton Aqueduct was built, about the year 1890, the art of drilling rock had been so far perfected, and the use of explosives, through the invention of dynamite, had become so general, that this waterway was planned and executed on straight lines, following rather than avoiding the rock. The second Croton Aqueduct is a tunnel through rock, about 32 miles in length; material gneiss, almost as hard as granite. Its construction was made practicable by sinking

shafts about one mile apart, thus providing multiple points of attack and also serving to ventilate the headings. This second aqueduct siphoned the water underneath the Harlem river. This 32-mile tunnel was built in five years. The Catskill Aqueduct, now nearing completion, not only followed the rock wherever it was available, but it passed under several rivers and actually conducts its water underneath the Hudson, where rock was sought and found at a depth of a quarter of a mile below the surface.

Pliny gives us a description of what, so far as we know, was the first long tunnel driven in the history of the world. This tunnel was about 3.5 miles long and from 6 to 10 ft. in diameter. Forty shafts were sunk in order to expedite the work, and it is said that 30,000 men were employed for 11 years in its construction. The fact that this tunnel and most of the ancient tunnels in the vicinity of Rome were driven through lime rock enables us to understand how it was even possible to build them. Limestone is the easiest material to perforate, and it is likely that here the ancient system of "firing" was used. Firing consisted of building a wood fire close to the rock and throwing water against the hot surfaces, causing them to flake. With lime rock the material would very likely be softened so that chisels might be used to advantage.

What is true of aqueducts is also true of railway tunnels and mines. The Hoosac Tunnel in Massachusetts developed, though it did not perfect, the rock drill. It was said after the completion of this work that only the treasury of a State made it possible to drive this tunnel by machinery. Had the mechanical engineer neglected the study of rock-drill economics it is doubtful that any further attempts would have been made to drive hard-rock tunnels by machinery, but the Hoosac was followed by the Musconetcong, driven from portal to portal by machinery. Then we have the Palisades, the Cascade, the Busk, and numerous other large railway tunnels made possible because the rock drill had been simplified and made efficient. In Europe the great Alpine tunnels, known as the St. Gothard, Arlberg, Simplon, and Loetschberg, one of them (the Simplon) being a continuous tunnel without shafts for a distance of 12.25 miles, were made practicable by the efficiency of the rock drill.

We seldom stop to think how important the rock drill has been in our industrial progress. Dr. Raymond has said that it is the foundation of all the work of the mining engineer. Railroads, even in America, might have successfully followed the foot-hills and hand drilling might have been a feeble substitute for the rock drill in leading through impassable barriers, but railway efficiency would have fallen far short of its present status and the cost of transportation by rail would have been greater than it is at present. In this we are able to see that the civil engineer might possibly have survived without rock-drill economics, but not so



with the mining engineer. The history of modern mining engineering is closely related to the history of progress in the art of building a rock drill. Our so-called precious metals would have been indeed precious without this valuable auxiliary. The wealth of the world, especially in its gold, silver, copper, zinc, lead, and tin, would have been enormously curtailed, limited by an inability to increase the output in proportion to the demand, and further limited by the fact that low-grade propositions could not have been worked at all. Examples of this are seen in the Homestake, the Alaska Treadwell, the mines of South Africa, and in most of the important mines of Michigan, which though once high-grade are now low-grade properties.

### EVOLUTION OF THE ROCK DRILL.

As late as October, 1910, E. M. Weston, of the Transvaal University College, writing on the subject of rock drills, said: "There is much vacant ground for careful and intelligent experiment and invention. Hammer drills are only now being developed, designs are changing every month, difficulties are being overcome and sometimes new ones encountered; nor has the last word been said in the design of piston drills." No better excuse may be given for this paper at this time than the fact, now generally admitted, that in the last two or three years the study of rock drill economics has been pursued so vigorously and so successfully that in design, material, and workmanship the rock drill of to-day is a superior machine, doing more work, standing up to its work longer and better adapted to conditions heretofore unknown than the machines of the past. Lighter in weight, and more easily handled by the operator, it is an aid to the miner in very materially reducing the cost of ore per unit of labor, repairs, and power consumption. There has in fact been an evolution in the rock drill from a piece of steel with a bit on the end of it, struck by the hand of an operator, to a similar piece of steel struck by a power hammer. Between these two extremes we have seen the jumper, the hand-operated drill, and the power-driven machine, which started with the cumbersome rock drill of J. J. Couch, about 1850, followed by the reciprocating machine of Joseph W. Fowle a few years later, Fowle's original idea of the cutting tool being an extension of the piston rod continuing to hold supremacy in many simplified forms up to a very recent period.

It is interesting to follow the evolution of the percussive type of rock drill. We must bear in mind that there are two distinct types of power-driven machines—the reciprocating and the hammer drill. Fowle's first machine was mounted upon wheels and weighed several thousand pounds. The Burleigh drill, which was a development of Fowle's invention, Burleigh having purchased the Fowle patents, was a machine mounted either upon a carriage or a tripod, but in any case it was difficult to get

the weight below a thousand pounds. André in his admirable work on coal mining, published a generation ago, states that a machine rock-drill should be "simple in construction and strong in every part." He follows this with the statement that it should be "as light in weight as can be made consistent with the first condition." The problem in percussive drills has always been to reduce the weight, provided in so doing the strength of the machine is not brought below the breaking point. The struggle to reduce the weight at first met with considerable success when air pressures of from 40 to 60 lb. were in vogue. It was found, however, that it paid in mining work to use high air pressures and this at first interfered with the efforts made by engineers to bring down the weight. There was even a period, some 20 years ago, when some engineers advocated heavy rock drills as best and most efficient in the end. Successful contractors specified large machines, claiming that by their use they were able to increase the air pressure, to get a heavier blow, to save up-keep expenses and to reduce the cost of excavation. Heavy drills invariably called for heavy mountings, and here is where an added difficulty was experienced, because heavy mountings were cumbersome underground, they were in the way, it was necessary to employ more men to handle them and they could not be used at all in narrow places. Here began the struggle for supremacy between the percussive and the hammer types,—a struggle which has recently resulted in the adoption of the hammer type as the most useful drill for general mining purposes.

### THE MODERN ROCK DRILL.

The mining drill at the present time is a machine which weighs from 60 to 150 lb. It is largely a one-man machine, though under many conditions of work it is still best to add a helper. The percussive or piston type still holds its supremacy for heavy work, even in mines where large stopes are encountered, as, for instance, at the Homestake, but this percussive drill is now a machine which safely withstands pressures of from 100 to 110 lb. and its weight has been considerably reduced because of changes made in both design and material. This type of drill now used in the stopes at the Homestake weighs 137 lb. unmounted, and mounted on column with arm about 375 lb. Its work is chiefly in down-holes. Each part of the machine represents a study in material. The metal itself and the treatment it receives in the shops are both regulated in accordance with the work that each particular part has to perform. All our knowledge of metallurgy is taken advantage of in the construction of the drill. The cast iron is not ordinary cast iron. It resembles it only in that the metal is cast. The composition is made up to suit rock-drill service and the metal is treated with special reference

to the work it is to do. The steel is not common steel, but it is alloyed to suit each particular part. It receives a hot, crude oil bath and it goes through many processes before it is finally coupled up with the other parts into a complete drill. Special metal and special treatment are not confined to the piston or percussive type, but they apply equally to the hammer type. In fact, it was because of the necessity for lighter weight and greater strength in the hammer type that the study of the metallurgy of the rock drill was initiated and carried to a successful issue.

The first great improvement made in the piston or percussive type has been in the metal used, and this has resulted in greater strength, greater durability, and a lighter weight of machine for higher pressures. There has also been a change in design, which in the main has been confined to the valve motion. The chief aim of the designer has been to get greater speed. This means a greater number of blows, and in order to do this valves have been provided which open and close quickly and which have large ports. It is obvious that, other things being equal, a piston type of drill of large piston area will do more work than the same type of drill with a smaller area. The larger machine, which drills more, is handicapped by its weight, and when the net efficiency is figured up it has been found that it sometimes pays to get less drilling capacity with a machine which is more readily handled. Here the question of upkeep is introduced, because generally speaking the heavy type of machine costs less for repairs than the lighter type. The designer, taking all these things into consideration, has sought to increase the diameter of the piston so as to provide the drilling capacity of the heavy type with a machine of considerably less size and weight. This has in a measure been accomplished by the use of superior material and a design which shortens the piston, putting the extra bearing into the front head, where it is lighter. Through the use of a type of valve known as the butterfly a quick opening of large area is provided, thus increasing the number of strokes and thereby bringing up the drilling capacity. This has been done with no increase in air consumption that is not compensated for by increased drilling power.

Air consumption in rock drills is much misunderstood. Assuming that the piston and valves are tight, in other words, where there is no leakage, air consumption is usually dependent upon the number of strokes delivered. It is assumed, of course, that a constant diameter and length of stroke are used and that the pressure is uniform. It is plain that if we are able to utilize air or steam at 100 lb. gauge pressure for the full length of stroke when a percussive drill delivers its blow we are going to get the best results in drilling capacity; that is, we are going to get the hardest blow that is commensurate with the diameter, length of stroke, and pressure of the machine. If this blow is too hard, that is, if it breaks the steel, destroys

the bit, or creates a condition where the drill is unmanageable on its mounting, then we have the alternative of reducing the size of the machine and in this way getting lighter weight, which is always desirable when it is consistent with the other conditions. We all know that the class of rock usually determines whether or not we are striking too hard a blow, but assuming that the class of rock is uniform, or that it is determined and understood, the engineer is obviously justified in providing a drill which will strike the hardest blow that the machine and the rock will stand without destructive consequences. We see, therefore, how important it is to start with a machine which has a valve motion and ports so designed that the full power pressure will follow the piston the full stroke until the blow is delivered. Having this condition, as light a machine should be used as will stand up to the work.

It naturally occurs to one that a quick-opening valve and a large port will bring about greater speed, but the question is asked, is not this condition wasteful in air consumption on the return or back stroke? It will be generally admitted that it pays to get the blow, but why should the same conditions that give us the blow obtain when the piston returns for another stroke? There are two reasons why this is advantageous. One is, that the pull-back on a piston type of rock drill is sometimes of as great importance in the long run as the blow. A weak pull-back reduces the speed of the machine, causing it to come back more slowly than it went forward, and it has the further disadvantage that holes that are not straight, or which are out of round, and where seams and other irregularities are encountered, will act to retard the steel during its reciprocations. This considerably reduces the efficiency of the machine, not only because it cuts down the number of blows delivered, but because it weakens the strength of blow. The steel is held back in its effort to reach the full stroke and a labored blow, with sometimes a shorter stroke, is the result. Now it is quite true that in good, clean, hard rock, without seams, and where holes are drilled to reasonable depths, it might pay to save air on the return stroke. As a matter of fact, this is always done in a piston drill because the diameter of the rod must be subtracted from the piston area. The percussive piston type of drill is naturally a compounded machine which hits a harder blow forward than backward, because it has the full piston area at one end and a reduced area at the other. It is not a difficult matter to regulate this to any degree desired by increasing or decreasing the size of the piston rod or by increasing or decreasing the valve and port areas on one end of the stroke and not on the other. But every attempt to compound a piston type of drill by putting a pressure in front of the piston is a mistake. Just in proportion as a pressure is introduced in the front end it would cushion or restrict the force of blow, and in doing this, as has been previously pointed out, we make it necessary

to increase the weight of the machine in order to get the effective maximum blow. It is, therefore, a very dangerous expedient in the design of piston drills to attempt to compound the stroke. Reduced air consumption is easily effected at the sacrifice of efficiency. Air at 100 lb. is delivered to a percussive drill at a cost that varies from 40c. to \$2 per day. To save 25 per cent. of this is all that compounding could reasonably be expected to accomplish, and this at the maximum is only 50c. a day. Experienced engineers will have no difficulty in seeing that there are many ways underground by which this and larger amounts may be lost through a machine which must inevitably be weakened in certain other directions in order to effect a small saving in air economy. Under most conditions of service it pays to conserve labor and upkeep expenses, giving first consideration to those things which cost most. A small reduction in drilling capacity, or a few idle hours, means an expense which will easily run in excess of any possible saving in air.

The hammer type of drill is a natural air saver, and it is in the design and construction of this type that air economies may be effected safely and without sacrifice. The hammer drill is essentially a machine for mines. It represents the evolution of the rock drill from the piece of steel struck by a hammer through the various stages of percussive machines back again to the hammer-driven blow upon the steel, the difference being only that the blow is a rapid power blow. A hammer drill is economical in air consumption because, in the first place, it reciprocates a light plunger which weighs only a few pounds, while with the piston drill not only must the heavy piston be thrown backward and forward at high speed, but it carries with it the steel and bit. In hammer drills the power is utilized, not in overcoming the inertia of a heavy body, but in compensating for that inertia through the high speed of a light body. A heavy mass moving slowly may give the same impact of blow as a light mass moving rapidly. The effective work done at the bottom of the hole is represented by the weight multiplied by the velocity. The same effect may be produced by subtracting from the weight and adding to the velocity, or *vice versa*. In a piston or percussive drill, velocity is limited, while in a hammer drill it is practically unlimited, and here is where the great possibilities of hammer drills have come in.

We must always bear in mind in comparing piston and hammer drills that the piston drill is handicapped by the load of the piston and steel, which has a certain inertia difficult to overcome in our efforts to reach high speed. The stroke is necessarily short, and as the hole gets deeper this handicap of weight is increased by longer steels, so that we are driven to high air pressures in order to get high speed. High air pressures naturally cost more money than low air pressures, and, as has been shown, if we attempt to save air by compounding we limit the capacity of the

drill to force itself through difficult places. In holes at or near the horizontal there is always an added disadvantage in a percussive type of drill, due to the steel dragging in the hole. This will take place even in a clean, straight, round hole. The steel sags, and in sagging, and during the process of rotation, there is considerable friction loss within the hole. All this leads us to high pressures, which is only another expression for greater power. It is safe to say that the piston type of drill has reached its limit when we consider capacity as a limitation when rating efficiency. In down-hole service, especially for deep holes and in soft rocks, piston drills will always be useful. The pumping action of the bit serves to agitate the material at the bottom, especially when mixed with water, and in this way the hole is kept more or less clean under the bit.

The study of rock-drill economics has led the mechanical engineer into the hammer-drill field as one which offered the greater possibilities. The problem was to do more work and with a lighter machine. The next consideration was to accomplish this with a reduced labor and power cost. All of these conditions have been met and, as subsequent figures will show, extraordinary results have been obtained which have materially reduced the cost of excavating rock and ore. We have seen that the process has been one of return to primitive methods. In other words, we have done what is most natural, and that which conforms closest to the laws of Nature is invariably best. The natural way to drill rock is to strike a piece of steel with a hammer. The only reason why the miner does not continue to do things in this way is because he cannot strike a sufficient number of blows. Just in proportion as he uses a heavier hammer does he reduce the number of blows that he is able to maintain and with the lighter hammer he is brought to an absolute limit. It would seem that the first thought of the engineer would have been to follow the old miner by building a rock drill on the hammer type. He may have thought of this, but the problem proved to be a very difficult one. The first difficulty was to get material that would stand up against this rapid-fire system. Then came the question of rotation, which was not easy to accomplish with a machine of the hammer design. Of equal importance was the question of keeping the bottom of the hole clean, because the bit being practically stationary at the bottom, the cuttings from the hole would pack between the edges of the bit and the bottom of the hole and prevent further progress. Jets of steam, of air, and of water were used to discharge the cuttings. Steam has many disadvantages, air is expensive and it creates dust, while water is, in the first place, difficult to introduce into the bottom of the hole, its mixture with parts of the drill results in wear and tear, and to use much water is a disadvantage and an expense in underground work. Up-hole work offers less difficulties for hammer-drill service than any other. The cuttings drop by gravity out of the hole

and the only disadvantage is dust. Horizontal hole work is that which is most difficult, while with down-holes water thrown into the hole always serves a useful purpose. A mixture of air and water has solved most of the problems arising from the use of hammer drills in mines. This is known as the Leyner system. Air is always available and is readily conducted in the hole, using either live or exhaust air. Where this air is commingled with water it discharges the cuttings from the bottom of the hole without blowing them away in the form of dust, but by simply reducing them to a puddle condition with enough water only to create a moderate stream, which discharges the cuttings through the orifice of the hole. This keeps the bit cool, there is enough puff to the air to remove the chips, and a long experience under all conditions of service has demonstrated conclusively that a mixture of air and water is more effective in cleaning the hole than even a large stream of water alone. In fact, air is the ideal thing to use, and it would be used alone were it not for the dust, so that the present system introduces only enough water to lay the dust. In doing this we effect economies by using only a small amount of water mixed with air from the exhaust.

The pneumatic tool, especially the type known as the riveter, illustrates the mechanical principles involved in the hammer drill. It is likely that the perfection of the pneumatic tool led to the perfection of the hammer drill. A riveter combines an extraordinary amount of power. Its efficiency is very high because the hammer speed is high, and the machine is light and easily handled. Its use in steel and iron construction is now universal. Air consumption in a tool of this nature is low in proportion to the work it does, because the thing reciprocated by the air is so light that it is easy to get high speed without sacrificing power to overcome inertia. In other words, there is a closer relation between the air pressure and the speed of hammer, with the resultant effective blow.

A point not to be lost sight of is that the rapid reciprocation of a flying piston, as in a hammer drill, is very much more easily mounted or held by an abutment than where we have a reciprocating action of a heavy weight, as in the case of a piston drill. The reasons for this are obvious. High speed of a light hammer takes the place of slow speed of a heavy hammer. One is like the rapid reciprocations of a hand hammer, the other the ponderous swing of a sledge. So great an effect is obtained by this rapid, light blow that it has been found practicable to reduce the weight to a figure considerably under 100 lb. in a machine which in drilling capacity compares favorably with a piston drill of two or three times the weight. In this light machine, material alone has not enabled us to cut down the weight, but the light rapidly moving piston design, with the quick-opening valve, is of equal importance. It would surprise a drill runner of 10 years ago to learn that hammer drills are used to-day in hard rock, putting

in holes 10 and 15 ft. in depth without even mounting the drill, it being held in the hand of the operator. Of equal importance in tunnel driving is the fact that by the use of hammer drills the equivalent of heavy machines is placed in the headings mounted upon a light horizontal bar, this bar being easily handled by a few men, yet it affords abutment enough to resist the jar, because the jar has been reduced to a minimum. Heavy upright columns, carriages, and other forms of support were made necessary because of the ponderous pulsations of the piston drill. To be able to use a light bar, placed horizontally, is of the greatest importance in tunnel driving because it affords an opportunity to begin drilling quickly after a blast and before the muck has been cleared away from the bottom of the heading. This has been referred to in detail in the paper of D. W. Brunton, Notes on the Laramie Tunnel.<sup>1</sup>

An effort has been made in the foregoing statements to analyze and give reasons for a condition in rock-drill service which is now in practical operation.

A hammer drill is the modern progressive miner. It has practically done away with hand drilling and in doing this it has largely increased the field of service. There is no longer any question about the fact that it pays to use power drills in all classes of mining. It is now entirely a question of adapting the system of mining to these light, efficient, handy perforators. In August, 1912, there was held at Calumet, Mich., what is perhaps the last contest between hand and power drilling. A three-man double-jack team of the best drillers in the copper country was pitted for a money prize against a small hammer drill of the Butterfly type. This machine was operated by one man. The drilling was in a block of Cape Ann granite, 60 in. thick. The three-man drilling team started with a 1¼-in. bit and finished with a 7⁄8-in. bit. The one man with the Butterfly (this is a light hand hammer drill, of the usual plugger type, weighing about 40 lb.) used a 2-in. starter and finished with a 1¼-in. bit. It required 14 min. for the machine to drill entirely through the block (60 in.), while the hammer-and-drill squad put in a 49-in. hole in the same time. The machine did 20 per cent. more work with one-third the labor cost. As a matter of fact, no such rate of hand drilling as was shown by the three-man squad could be maintained over a working shift, while there is no reason why the machine drill should not keep up its speed indefinitely.

#### CLASSIFICATION OF ROCK DRILLS.

It may be interesting to classify the present types of drills as follows:

1. The plugger drill. This is of the hammer type. It is used in its

<sup>1</sup> *Trans.*, xliii, 99 (1912).



smallest sizes for dressing stone, for trimming, cutting hitches, and for block holes. It is a hand-rotated machine.

2. The Jackhammer. A hammer drill with automatic rotation, used for sinking shafts, for down-hole work in stopes, for quarrying, for drilling in coal, and in rock and ore work wherever down-holes are required. It is held in the hand of the operator and in some mines is used for horizontal work, mounted upon some simple form of support.

3. The stopper. A hammer drill with air feed, usually used without mounting and for up-holes. It has a large field of usefulness, mainly in stopes or rooms and in driving raises.

4. The mounted hammer drill, as exemplified in the Leyner type, used mainly for horizontal, or approximately horizontal, hole drilling, for side stopping, and for driving drifts and tunnels. In this type of drill a combined stream of air and water is discharged through a hollow steel at the bottom of the drill hole.

5. The reciprocating drill, used for heavy down-hole drilling where the stopes are large, and for surface work, drilling deep holes of large diameter.



Fig. 1.

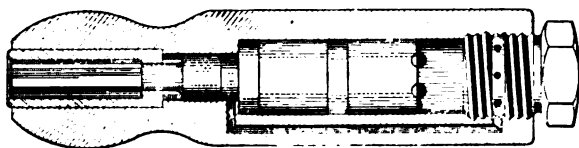


Fig. 2.

FIGS. 1 AND 2.—SIMPLEST FORM OF PLUGGER DRILL.

These stone tools are designed to meet the usual requirements in stone dressing. The several sizes cover a variety of work, from the heaviest cutting to the most delicate tracing. The tool is valveless, hence there is but one moving part and that a hardened piece of steel.

Figs. 1 and 2 are a photograph and a sectional view of the simplest form of plugger drill. Fig. 3 shows the machine in use in dressing stone.

Plugger drills are largely used for pop shooting, breaking up boulders, trimming walls, and for all light work requiring holes not exceeding 5 ft. in depth. Solid or hollow steel may be used. In the latter case the exhaust air is discharged at the bottom of the hole for the purpose of removing the cuttings. This type of machine is equipped with a simple device for

cleaning the holes of rock cuttings which may not have been discharged by the normal process of exhausting in the hole. This device consists of a lever, eccentric in its middle portion and located on the side of the valve chest. A portion of the lever forces a plunger against the valve, stopping the action of both the valve and the hammer piston and thus permitting



FIG. 3.—DRESSING STONE WITH PLUGGER DRILLS.

live air to pass to the bottom of the hole. Where steam is used wooden handles replace the metal ones. Fig. 4 shows the plugger drill for drilling holes, while Fig. 5 is a view showing the drills in operation.

### 1. The Plugger Drill.

#### *Specifications of Stone-Working Plugger.*

| Size Symbol.....                               | AA. | AB. | AC.  | AD.  |
|------------------------------------------------|-----|-----|------|------|
| Weight, pounds and ounces.....                 | 1—5 | 2   | 3—9½ | 5—1½ |
| Length over all, inches.....                   | 5½  | 6½  | 7¾   | 8¼   |
| Outside diameter, inches.....                  | 1¾  | 1½  | 1½   | 1¾   |
| Diameter of piston, inches.....                | 5/8 | ¾   | 1    | 1¼   |
| Total length of stroke, inches.....            | 1½  | 5/8 | 1½   | 1½   |
| Length of stroke to working point, inches..... | 1½  | 1½  | 1½   | 1½   |
| Air consumption, cubic feet.....               | 2   | 3   | 4    | 5.5  |

*Specifications of the Plugger Rock Drill.*

|                                       | BA.    | BC. |
|---------------------------------------|--------|-----|
| Length, inches.....                   | 22½    | 24  |
| Cylinder diameter, inches.....        | 1½     | 2   |
| Stroke, inches.....                   | 3½     | 4   |
| Steel used (hollow hex.), inches..... | ⅞ or 1 | 1   |
| Air inlet, inches.....                | ½      | ½   |
| Weight of 23 type, pounds.....        | 43     | 54  |
| Weight of 26 type, pounds.....        | 48     | 65  |

*2. The Jackhammer.*

The Jackhammer, Figs. 6 and 7, can be operated either by steam or air, it uses hollow steels, is provided with an automatic rotation and it drills

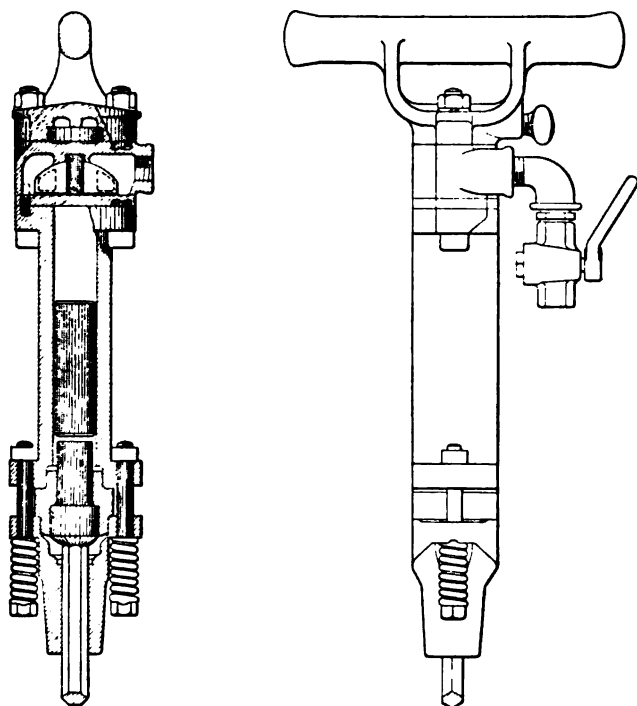


FIG. 4.—PLUGGER FOR DRILLING HOLES.

holes to a depth of 15 ft. It is essentially an all-steel drill. The cylinder, for instance, is drop forged, made of special steel, treated and hardened in the bore. Its most interesting feature is its automatic rotation, which is shown in the skeleton section, Fig. 7. Fig. 8 is a view of Jackhamers engaged in stoping in No. 15 shaft, seventh level, Osceola Amygdaloidal lode of the Calumet and Hecla mine, Calumet, Mich.

*Specifications of Jackhammer.*

|                                          |    |
|------------------------------------------|----|
| Length, inches .....                     | 18 |
| Cylinder diameter, inches .....          | 2¼ |
| Stroke, inches .....                     | 2  |
| Steel used, hollow hexagon, inches ..... | ⅞  |
| Size of air hose, inches .....           | ¾  |
| Weight, pounds .....                     | 40 |

*3. The Stoper Drill.*

The stoper hammer drill is so well known and so generally used that further description is unnecessary. It is but a few years since this machine

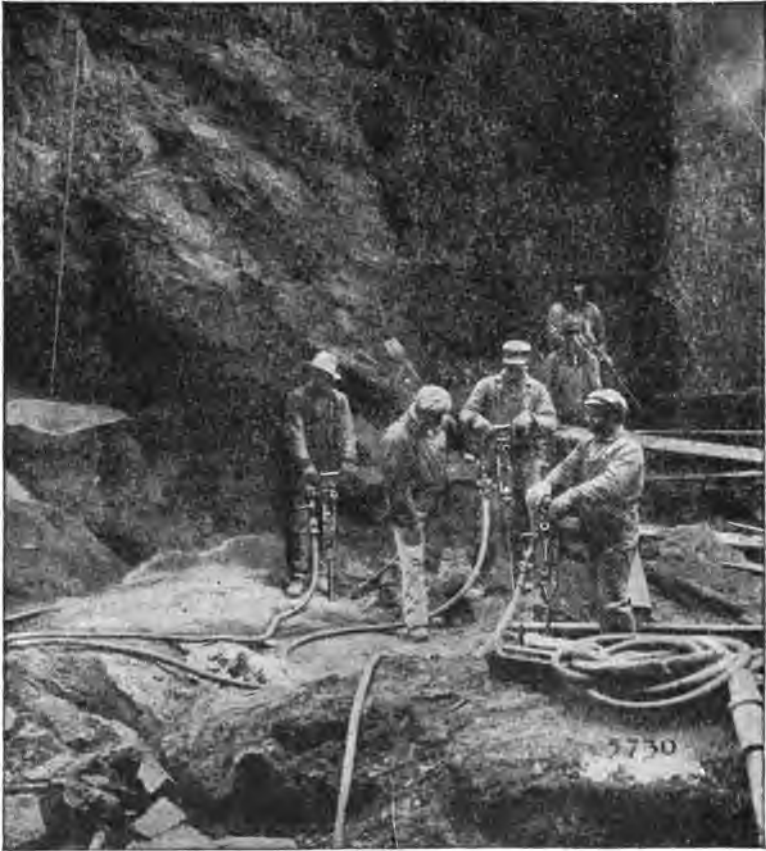


FIG. 5.—PLUGGER DRILLS IN OPERATION AT GRAND CENTRAL TERMINAL, NEW YORK.

was invented and its application to general mining work has been very rapid. Thousands of them are in use. Fig. 9 is a sectional view and Fig. 10 shows a stoper in operation. In this particular case a jet discharges a spray of water for allaying the dust.

*Specifications of Sloper Drill.*

|                                                    |     |
|----------------------------------------------------|-----|
| Piston diameter, inches.....                       | 2   |
| Piston stroke, inches.....                         | 4   |
| Length of feed, inches.....                        | 22  |
| Length of machine over all (closed), inches.....   | 52½ |
| Length of machine over all (extended), inches..... | 74½ |
| Weight, pounds.....                                | 73  |
| Size air hose, inch.....                           | ¾   |



FIG. 6.—VIEW OF JACKHAMER.

*4. The Water Leyner Drill.*

The water Leyner drill is shown in section in Fig. 11. Fig. 12 is a photographic view of a drill of the Leyner type driving an inclined raise in No. 15 shaft, Osceola Amygdaloidal lode of the Calumet and Hecla mine. This machine was in actual operation when the picture was taken.

*Specifications of Water Leyner Drill.*

|                                                                |                  |
|----------------------------------------------------------------|------------------|
| Weight, drill only, 24-in. feed (standard), pounds.....        | 150              |
| Length over all, 24-in. feed (standard), inches.....           | 47 $\frac{3}{4}$ |
| Weight, drill only, 30-in. feed (special), pounds.....         | 160              |
| Length over all, 30-in. feed (special), inches.....            | 53 $\frac{3}{4}$ |
| Bore of cylinder, inches.....                                  | 2 $\frac{1}{2}$  |
| Length of stroke of hammer, inches.....                        | 3                |
| Size of air inlet, inches.....                                 | $\frac{3}{4}$    |
| Size of water inlet, inches.....                               | $\frac{1}{2}$    |
| Standard hollow round drill steel and shank, inches.....       | 1 $\frac{1}{4}$  |
| Most economical depth to which holes can be drilled, feet..... | 8 to 12          |

*Air Consumption.*

|            |            |            |            |             |
|------------|------------|------------|------------|-------------|
| 60 lb.     | 70 lb.     | 80 lb.     | 90 lb.     | 100 lb.     |
| 64 cu. ft. | 75 cu. ft. | 87 cu. ft. | 98 cu. ft. | 109 cu. ft. |

## RECORDS OF RECENT EXPERIENCES.

There is no place where this new type of Jackhammer drill shows to better advantage than in shaft sinking and in bench or foot-wall work in mines and tunnels. For shaft work two or three times the number of



FIG. 7.—SKELETON VIEW OF JACKHAMER.

drills may be used as formerly. Each man in the shaft who is not engaged in mucking is a driller, the two operations being carried on simultaneously.

At the Newport mine in the Lake Superior iron country a shaft is being driven with Jackhamers. Dimensions of shaft, 11 by 18 ft. in the clear. The progress has averaged 20 ft. per week, using five drills; material, hard quartzite. During February last a progress of 107 ft. was reported, and in March 125 ft., this latter being said to be the record of performance in shaft sinking in that district.

At the Lucky Star mine in the Lake Superior district four Jackhamers are working in a shaft 12 ft. 2 in. by 14 ft. 10 in., drilling ten 6-ft. holes for sinking and twenty 5-ft. holes for squaring after blasting; material, hard diorite. The progress has averaged about 100 ft. per month.

The Norrie-Aurora shaft of the Oliver Mining Co. was sunk 64 ft. in February, employing three 8-hr. shifts of eight men, each using Jackhammer drills, the shaft being sunk, steel timbered and concrete lined. The total

hours drilling was 794 man-hours, out of a total of 4,202 man-hours. In this performance the man-hours required for mucking were almost twice that of the drilling, whereas the time charged for blasting approximated that of the drilling; the timbering and lathing combined were slightly under the drilling figure. The remainder of the time was charged to squaring, cutting hitches, piping, etc. During March 105 ft. of shaft were driven and completed. This included not alone the sinking of the shaft,



FIG. 8.—STOPING WITH JACKHAMERS IN CALUMET AND HECLA MINE, CALUMET, MICH.

but the heavy steel sets were placed in position, the concrete slab-lathing was put in place for the entire distance, also the back-runners. The magnitude of the work may be better understood when it is realized that 24,600 cu. ft. of rock were broken and hoisted to the surface, and the labor of placing the shaft equipment, consisting of two skip roads, one cage road, ladderway, pipe compartment, counter balance and back-runners, completing a modern five-compartment shaft, was all performed in 26 days. Each piece of concrete slab-lathing weighed 130 lb. and the steel sets were made of heavy material. Six Jackhammers were used to sink the shaft.

The East Butte Copper Mining Co. is sinking a shaft through a hard

granite formation with two Jackhamers, from the 1,200-ft. level to the 1,800-ft. level, and reports show that from Jan. 20 to Feb. 15 of the present year 110 ft. of shaft were driven, including timbering. During this period they lost 11 shifts due to outside causes, no work whatever being done. Here an average of 28 holes was drilled per shift, 8 cuts 9 ft. deep, 8 lifters 6 ft. deep, 6 back holes 6 ft. deep and 6 end holes 6 ft. deep. Occasionally as high as 33 holes were drilled. The average net drilling time was 5 hr. This gives a total hole footage per shift of 192 ft., or 96 ft. per drill, an

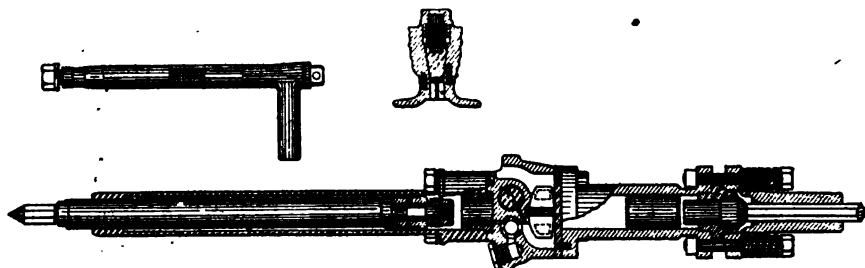


FIG. 9.—SECTIONAL VIEW OF STOPPER.

average of 19.5 ft. per drill per hour. The previous best progress, made with heavy tripod drills, was 60 ft. in one month. Size of shaft, 19 ft. 6 in. by 6 ft. 10 in.

J. A. McIlwee, the contractor who drove the Laramie-Poudre tunnel, is sinking a shaft for the Silver King Consolidated mine, Park City, Utah. This is a three-compartment shaft and is being driven a distance of 500 ft. from the 1,300-ft. to the 1,800-ft. level. The work began Mar. 22 with four Jackhammer drills, two on each side of the shaft; four drillers were employed. A great many delays and drawbacks were experienced, mainly on account of water. Some boiler difficulties were incurred, which caused a delay of four days in April. Notwithstanding this, 105 ft. of actual sinking or 95 ft. of completed and timbered shaft have been accomplished. Based on the number of days actually at work sinking, this is a progress of about 5 ft. per day. Holes were drilled 5 ft. deep, the usual time employed being 10.5 min. per hole. The best time made in drilling was 33 holes 5 ft. deep, with 6-ft. cut holes, in 2 hr. 45 min.; three shifts, each shift gang doing the drilling, mucking, and timbering.

Bench or foot-wall work has heretofore been done with large drills, employing from two to three men per drill. Deep holes of large diameter have been drilled, but during recent years the hammer type, both in the stopper and in the Jackhammer, has replaced the heavier machines for this class of work. In one of the Lake Superior copper mines recent extensive tests have shown the following figures:





FIG. 10.—STOPPER IN OPERATION WITH JET OF WATER FOR ALLAYING DUST.

| Type of Drill.  | Tons per Man<br>per Shift. | Mining<br>Cost per Ton. |
|-----------------|----------------------------|-------------------------|
| Stoper.....     | 13                         | \$0.41                  |
| Piston.....     | 12                         | 0.54                    |
| Jackhammer..... | 38                         | 0.12                    |

No overhead charges are included in the above figures of cost, nor are charges for air included. This effective saving by the use of stoper drills over the heavier tripod type, and the still further saving by the use of Jackhammers, cannot be maintained in all classes of work. In this particular case the bench or foot-wall afforded the best opportunity for the use of these little Jackhammer drills.

An analysis of the drill situation, in the iron fields of Lake Superior, indicates that four types of drills are necessary for the economical extraction of the ore, their relative proportion being about as follows:

|                                      | Per Cent. |
|--------------------------------------|-----------|
| 1. Mounted hammer drill.....         | 20        |
| 2. Stope drills.....                 | 20        |
| 3. Jackhammer or sinking drills..... | 10        |
| 4. Light piston drill.....           | 50        |

There will always remain a small percentage of drilling for which the two-man piston drill will still be the favorite. An instance is the operation of the Soudan mine at Tower, where the rock encountered is very hard; in fact, it is characterized as the hardest in the United States.

At this time the ore is very hard and dry, and the chief problem is not so much one to be met by the use of some particular type of drill, but rather one of getting the steel to stand, as the bits will not hold in this rock. Records show that as many as 80 starters have been used, with a 3.25-in. machine, to drill a hole 6 in. in depth. Light one-man drills have been tried in this formation, but without success.

In the hematite mines of Lake Superior the light reciprocating mining drill is generally used for the actual breaking of probably 90 per cent. of the ore which requires drilling (hand-auger ground excepted). In this class of work the service required of the drill is light, the ground being classed as very soft drilling, but of such a character as to bring it under the classification of "too hard drilling" for hand augers.

The three charts, Figs. 13, 14, and 15, show a three days' drilling record at the Winona mine, in the Lake Superior copper country. They are typical of the modern trend toward scientific management and greater efficiency in mining operations and are largely a result of the occasional low prices for copper, the decreased percentage of metal in the rock in mines which have been operated for years, and the introduction of labor reducing and time saving devices for the mine.

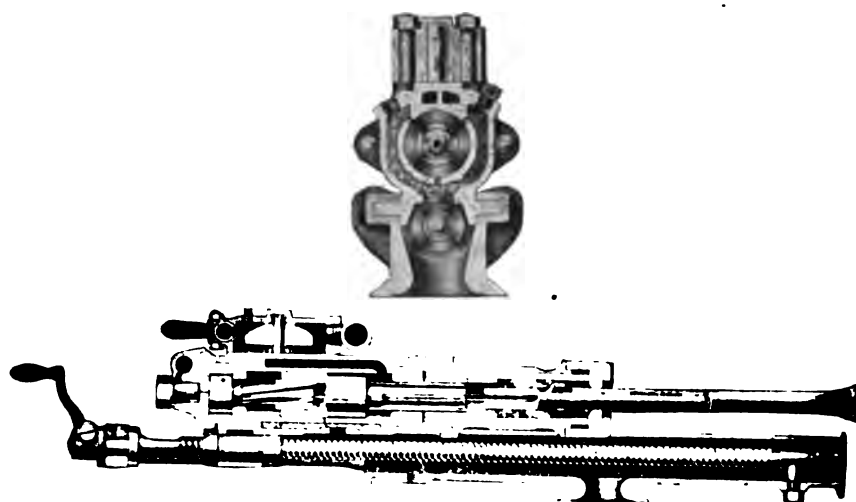


FIG. 11.—SECTIONAL VIEWS OF THE WATER LEYNER DRILL.



FIG. 12.—LEYNER TYPE OF DRILL DRIVING AN INCLINED RAISE IN THE CALUMET AND HECLA MINE.



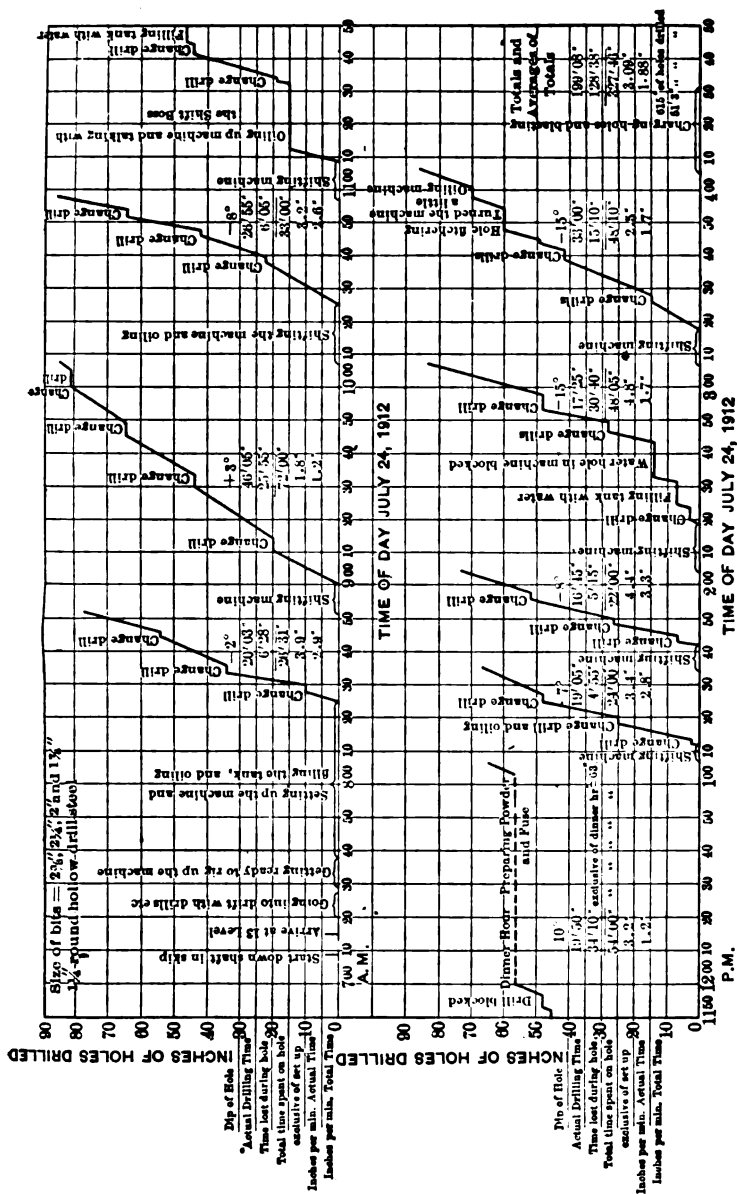


FIG. 14.—DRILLING RECORD FOR ONE SHIFT WITH A No. 18 INGERSOLL LEYNER DRILL.

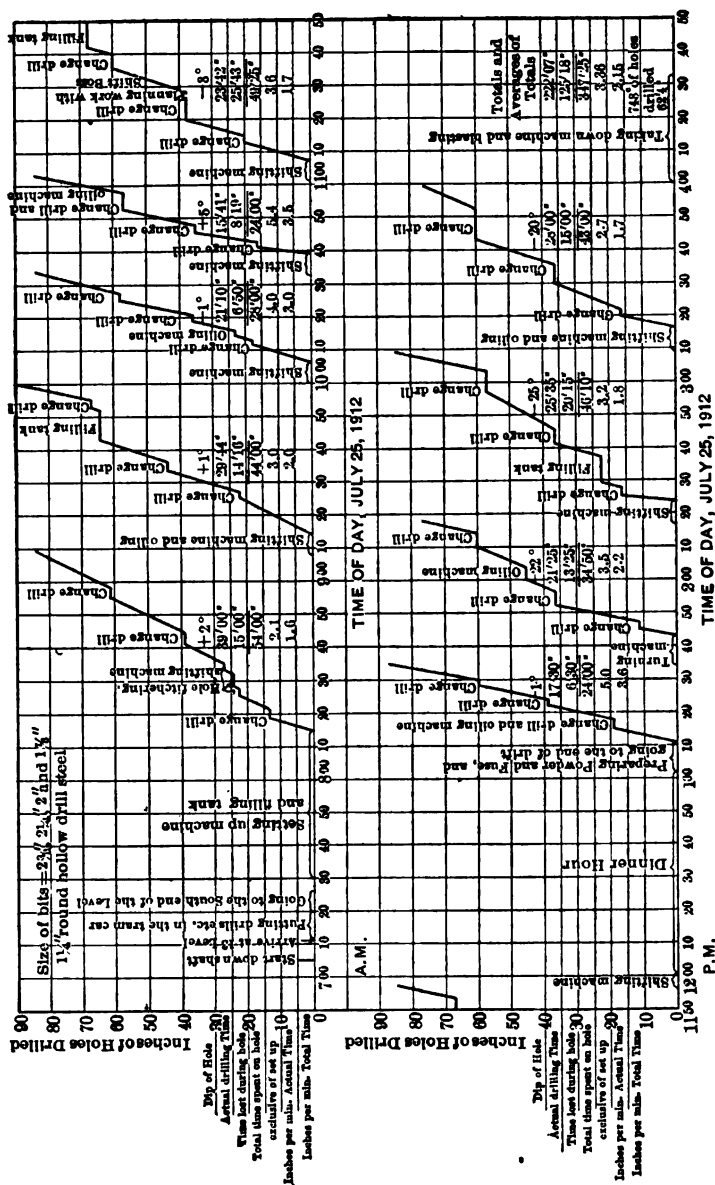


FIG. 15.—DRILLING RECORD FOR ONE SHIFT WITH A No. 18 INGERSOLL LEYNER DRILL.

In these charts the horizontal lines represent time of performance and the vertical lines distance drilled.

The completeness of the charts will be noted; every minute of the 9-hr. working shift is accounted for.

For instance, Fig. 13 shows that the actual drilling did not begin until 8.18 a.m. The machine then drilled a hole 16 in. deep in 3 min., when it was stopped to change steels, which operation required 1 min., and a further distance was then drilled of 20 in., requiring 3 min., when the machine was again stopped to change steels, 4 min. being consumed in doing so. Drilling was then continued and the hole deepened 15 in. in 3.5 min. The total time consumed in actual drilling was 9.5 min.; total time changing steels, 5 min.; and total depth of hole, 51 in. At this stage the machine was shifted for drilling a new hole.

In the city of Pittsburgh Jackhamers are being employed for driving an 8 by 12 ft. sewer tunnel, 1,200 ft. long. The formation is a hard slate and shale with a decomposed rock top. Single cap timbers are installed and it is necessary to use fore-poling to hold the top. Two drills are installed in the heading, drilling eight 3-ft. holes, with a single steel to the hole. The average drilling speed is 12 in. per minute. Owing to the bad top and the fact that the tunnel passes under two bridge piers and the Pennsylvania Railroad tracks, the shooting is necessarily light; about 2.5 ft. are pulled at each round. Ten feet of completely timbered heading is the advance per day of two shifts.

The following is a record of work done with Jackhamers in the excavation for the Grand Central Station, New York City:

| Month.              | Hours<br>Drilled. | Total Linear<br>Feet Drilled. | Average Feet<br>Drilled per Hour. |
|---------------------|-------------------|-------------------------------|-----------------------------------|
| Sept. 22 to 29..... | 60                | 950                           | 15 5/6                            |
| Oct. 1 to 31.....   | 255               | 4,256                         | 16.65                             |
| Nov. 1 to 5.....    | 48                | 800                           | 16 2/3                            |
|                     | <hr/> 363         | <hr/> 6,006                   | <hr/> 16.5                        |

Cost for repairs (2 pawls, 50c. each), \$1, or about 1 1/2 c. per 100 ft. drilled.

Air pressure, 70 to 90 lb.

Holes drilled, 4 to 10 ft. in hard New York mica schist.

Performance of Jackhammer at the Rockland & Rockport Lime Co., Rockland, Maine:

| Total Number Feet. | Total Hours. | Rate per Man<br>per Hour. |
|--------------------|--------------|---------------------------|
| 350.....           | 55           | \$0.20                    |
| 488.....           | 60           | 0.22 1/2                  |
| 372.....           | 55           | 0.22 1/2                  |
| 240.....           | 30           | 0.22 1/2                  |

*Week of May 4 to 10.*

| Total Number Feet. | Total Hours. | Ft. per Hr. | Rate per Man<br>per Hour. | Cost per Foot,<br>Labor Only. |
|--------------------|--------------|-------------|---------------------------|-------------------------------|
| 650.....           | 60           | 10.8        | \$0.22½                   | \$0.0208                      |
| 322.....           | 45           | 7.1         | 0.22½                     | 0.0314                        |
| 430.....           | 50           | 8.6         | 0.22½                     | 0.0262                        |
| 420.....           | 50           | 8.4         | 0.22½                     | 0.0268                        |

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 1822

The average cost per foot being \$0.0253.

The diameters of the bits used are as follows:

| Length of Steel,<br>Feet. | Diameter of Bit,<br>Inches. |
|---------------------------|-----------------------------|
| 2                         | 2                           |
| 4                         | 1⅞                          |
| 6                         | 1¾                          |
| 8                         | 1⅝                          |
| 10                        | 1½                          |
| 12                        | 1⅓                          |

The depth of each hole drilled was 12 ft.

In the lead mines in southeast Missouri they have heretofore drilled the down-holes in the stopes with the large type of two-man drill. Since the Jackhamer has been introduced in these mines the results obtained have been 60 to 80 ft. of 8-ft. holes per man per shift, while with the old system employing two men they were only able to drill 40 to 50 ft. of 8-ft. holes per shift. In many cases where the vein is exceedingly wide they drill 10-ft. holes as easily and readily as an 8-ft. hole can be drilled.

In the Oliver iron mines in Michigan the record is given as 57 stoper drills operated in the year 1912, with a total expense for repairs for the year of \$920.23, or \$16.14 per machine per year.



TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.  
[SUBJECT TO REVISION]

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Butte meeting, Aug. 13 to 21, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1913, when Vol. XLVI of the Transactions will go to press. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## The Compressed Air System of the Anaconda Copper Mining Co., Butte, Mont.

BY BRUNO V. NORDBERG, MILWAUKEE, WIS.

(Butte Meeting, August, 1913.)

THE high cost of coal in Butte and the development of large amounts of cheap electric power from the Missouri river caused the Anaconda Copper Mining Co. in 1908 to make an investigation as to the possibility of adapt-

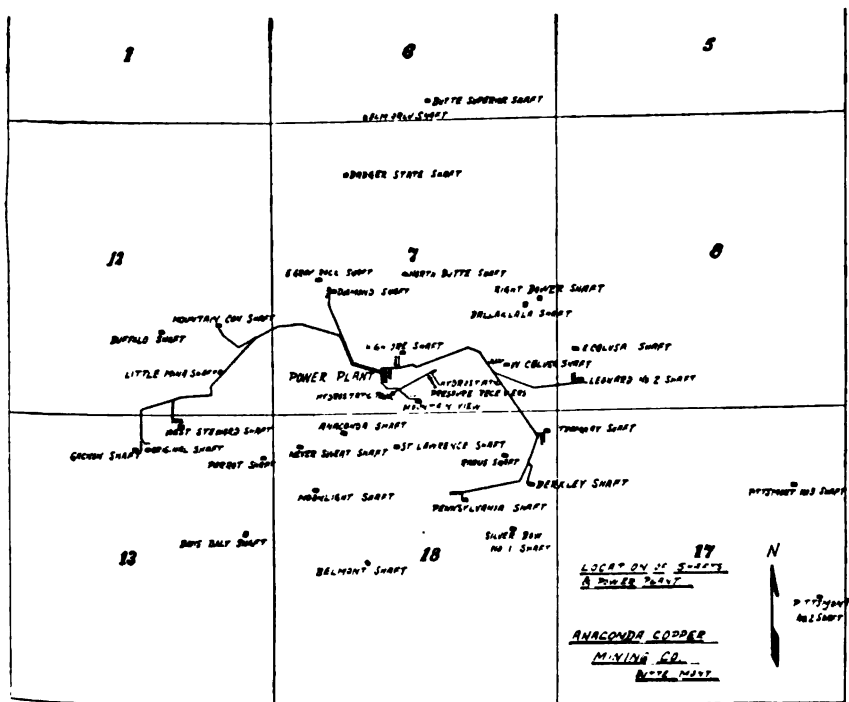


FIG. 1.—MAP OF BUTTE MINING DISTRICT.

ing this cheap electric power for the operation of their many large hoisting plants. At this time electric power had already been adopted for practically all other power purposes around the mines, such as pumping, compressing air, etc.

The map (Fig. 1) shows the location of the mines of the Butte mining district. These mines are located within a circle of approximately a 1-mile

radius. The shafts are all vertical, the maximum depth being 2,000 to 2,800 ft. at present, but sinking to greater depth is in progress in several shafts which are expected, in the future, to reach an ultimate depth of at least 3,500 ft. The hoisting is done from a great many levels between 1,000 ft. and bottom of the mine.

Every mine has its own dry house, which requires a boiler plant.

For the purpose of making this investigation it was determined to make extensive tests of four representative steam hoists of the district, namely, at the Speculator shaft of the North Butte Mining Co., and the Diamond, High Ore and Mountain View shafts of the Anaconda company.

At the Speculator shaft the hoist is a Nordberg, having steam cylinders 32 and 32 by 72 in. with Corliss valve gear. The drums are smooth, 12 ft. in diameter, carrying 1.5-in. round rope in two layers, operated by means of clutches.

At the Diamond shaft the hoist was originally built by the Risdon Iron Works but had been twice rebuilt by the Anaconda Copper Mining Co. It had steam cylinders 30 and 30 by 72 in. with Corliss valve gear and link motion reverse. It was equipped with reels carrying flat rope 0.5 by 7 in.

At the High Ore shaft, the hoist was built by the Union Iron Works. The cylinders were 30 and 30 by 72 in. with poppet valves operated by wrist plate motion with link reverse. This hoist was also equipped with reels carrying flat rope 0.5 by 7 in.

The Mountain View hoist was a Webster, Camp & Lane with cylinders 28 and 28 by 72 in., having Corliss valves with link motion reverse. It was equipped with reels carrying flat rope 0.5 by 7 in.

In passing it should be noted that several of the hoisting engines at Butte have to be located very close to the shafts, which necessitates reels and flat ropes to eliminate an otherwise prohibitive fleeting angle.

The tests were made by H. W. Dow and B. V. Nordberg, Jr., representatives of the Nordberg Manufacturing Co. Those directing the tests deserve great credit for the persistency with which they worked to get a sufficient number of readings to give an accurate record of the hoistings, without which it would not have been possible to determine the different factors entering into the power problem of the hoisting system.

The main object of these tests was to determine the power required and the nature of the load. In order to do this it was necessary to determine the exact time and duration of every trip, the load hoisted and the depth from which it was hoisted in or out of balance, as well as the speed conditions during each trip.

In order to get a record of the hoisting operations, a Karlik tachograph was used. This instrument draws a velocity diagram of every trip made

by the hoist with the velocity as ordinates and hoisting time as abscissæ, and gives a 24-hr. record on a paper 8 by 42 in.

The areas of the different diagrams represent the hoisting depth, but as these diagrams are very small and do not give the weight hoisted, it was necessary to obtain written logs of the hoisting for periods extending over 24 hours. Several such logs were obtained in which were noted the exact time of starting and stopping for each trip, the nature of the load hoisted or lowered (ore, waste, men, tools, etc.), the depth from which it was hoisted, or the distance lowered, and a statement showing if the hoist was in or out of balance. In order to prepare such a log the investigators had to stand watches of 24 hr. and carefully record every movement of the hoist during that time. This they did, so that the tachograph cards, which were a check on their vigilance, absolutely correspond with the written logs.

In order to determine accurately the weight of the rock handled per skip load, the ore bins at the North Butte mine were thoroughly cleaned just before and just after writing a 24-hr. log. All of the ore hoisted during this period was loaded into marked cars and the gross tare and net weights obtained from the smelter when unloaded. To determine the weight of the men it was found, by repeated trials that eight men, or the load per cage, as they would ordinarily fall into line, would average 160 lb. each.

All the odd material, such as timbers, supplies and poor rock handled up or down the shaft, was weighed at the surface. With all these weights, supplementing the written log, the shaft horsepower was calculated for each of the mines over a 24-hr. period.

Continuous indicator cards were taken, hoisting from every level, and hoisting every different kind of a load in balance and out of balance, and note was made on the tachograph card of the trips during which the indicator cards were taken.

Crosby continuous indicators were used and provided with electric pencil attachment, so that all four indicators worked simultaneously. By this means cards were obtained for every revolution made by the hoist for every given trip, thus giving a perfect record of the mean effective pressure and the resultant indicated horsepower.

In order to determine accurately the instantaneous revolutions per minute of the engine or rope speed corresponding to each individual indicator card, a special instrument was constructed. This instrument carried a continuous sheet of paper 15 in. wide which traveled at a perfectly uniform rate of speed, thus measuring time accurately. Moving at right angles to the travel of the paper was a pen having a reduced motion taken from the shaft driving the hoist miniature. Thus the curves drawn by this instrument had time as abscissæ and revolutions

of the engine or rope travel as ordinates. In what follows these curves will be referred to as "time distance" curves, or diagrams.

These curves were constructed on a sufficiently large scale so that velocities at any point can be determined by finding the value of the tangent to the curve at that point, and after having constructed such a velocity diagram, acceleration at any point would be determined by finding the value of the tangent to the velocity curve at that point.

In this paper, the term shaft horsepower means the actual net unbalanced load in pounds multiplied by the distance hoisted or lowered in feet, reduced to horsepower and does not include friction of any sort.

The following figures give a fair idea of the conditions under which the large hoisting plants in Butte have to operate:

### *Balanced Hoisting.*

Ore hoisted per trip, 5 to 6 tons.

Hoisting depth average, 1,800 ft.

Hoisting ore in balance, 31 loads in 35 min. from 1,800 ft. depth, equivalent to 582 average shaft horsepower for full load of 6 tons.

Duration of single trip, 51 sec. average.

Work to be done per single trip, 770 shaft horsepower.

The following are the particulars of the loads carried on these hoists:

|                | Kind<br>of<br>Hoist | Weight<br>Rope for<br>1,800 ft.<br>depth,<br>lb. | Skip and<br>Cage,<br>lb. | Total<br>Dead<br>Load,<br>lb. | Normal<br>Load<br>Ore,<br>lb. | Ratio<br>Dead<br>Load to<br>Ore<br>Hoisted |
|----------------|---------------------|--------------------------------------------------|--------------------------|-------------------------------|-------------------------------|--------------------------------------------|
| Speculator.... | Drum                | 4,800                                            | 11,000                   | 15,800                        | 10,000                        | 1.58                                       |
| Diamond.....   | Reel                | 10,700                                           | 11,000                   | 22,700                        | 10,000                        | 2.27                                       |
| High Ore.....  | Reel                | 10,700                                           | 11,000                   | 22,700                        | 8,000                         | 2.84                                       |
| Mountain View  | Reel                | 10,700                                           | 11,000                   | 22,700                        | 10,000                        | 2.27                                       |

The "dead loads" are here given for the average hoisting depth which is 1,800 ft. It will be noticed that these dead loads are much greater than in average hoisting practice. This is largely due to the Butte practice of permanently attaching a cage to the skip, the combined weight of which is equal or greater than the weight of ore hoisted, while in average hoisting practice the skip weighs from 60 to 70 per cent. of the ore it contains. Then again, when flat ropes are used to go down to 3,000-3,500 ft. depths, these ropes become very heavy and increase the dead loads correspondingly.

In average hoisting practice the dead loads for 10,000 lb. of ore hoisted per trip would be 10,400 lb. if the hoist was carrying strong enough rope for an ultimate depth of 3,500 ft.

The magnitude of the dead loads in a hoist is an important factor in the mechanical efficiency of the hoisting operation, as it influences the friction and the dynamic energy that has to be supplied to the hoist in getting up to speed and released when retarding the hoist. Ordinarily this dynamic energy is lost in form of heat on the brake shoes.

Occasionally it is required to lift unbalanced loads from various depths. In some mines such unbalanced loads come most frequently from the bottom of the mine. At North Butte considerable unbalanced hoisting was done from 2,200 ft. depth. Hoisting the skip and cages weighing 11,000 lb., one-half of the rope, 4,000 lb., and the load of 12,000 lb., or a total of 27,000 lb. from 2,200 ft. gives us:

$$\frac{27000 \times 2200}{33000} = 1800 \text{ shaft horsepower}$$

the work being performed in one minute.

At the Mountain View some of these unbalanced loads represented about 2,000 h. p. at the shaft. The average work per day of these hoists ranges from 25 to 110 shaft horsepower, based on the productive work.

The chart (Fig. 2), in which the effective work performed at the shaft is plotted over the dial of a clock, gives a good idea of the continuity of hoisting at these mines. The charts show the work done at the Speculator Shaft Jan. 11 and 12, 1909, and is a good average of the operation at the mine. Only the productive work, that is, the work represented by the hoisting of ore, is plotted.

From the tachograph diagrams and the log, the weight hoisted and the depth were determined, also the time during which the work was done. Thus, for instance, there were hoisted from 12:00 to 12:45 a. m. 31 loads from 1,800 ft. depth, or 155 tons, representing an average work of:

$$\frac{155 \times 1800}{45} = 6200 \text{ foot tons per minute} = 376 \text{ shaft horsepower during that period.}$$

The variation in the load during the period under consideration as determined from continuous indicator diagrams (Fig. 3), time distance curves (Fig. 4) and tachograph cards (Fig. 5) is shown in Fig. 6.

Frequently unbalanced hoisting was done when one compartment was obstructed. Figs. 7, 8 and 9 show tachograph card, power curve and continuous indicator diagrams taken March 8, 1909. Following a period of hoisting ore in balance from the 1,800 ft. level the station tenders were lowered to the 2,200 ft. level and ore hoisted from there out of balance.

A glance at the diagrams showing the power when hoisting in balance from 1,800 ft. depth (Fig. 6) shows that the horsepower fluctuates from +2,300 to -1,600 i. h. p., the average during this period being 630 i. h. p.

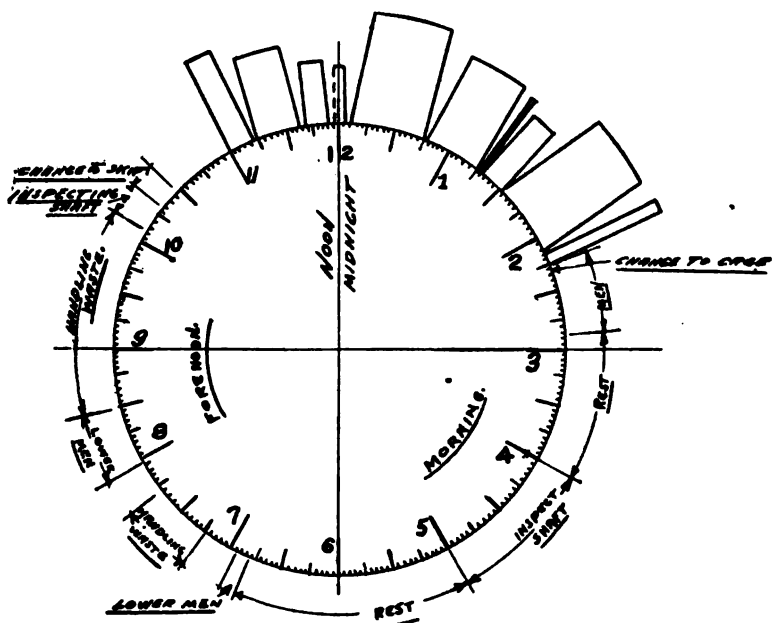
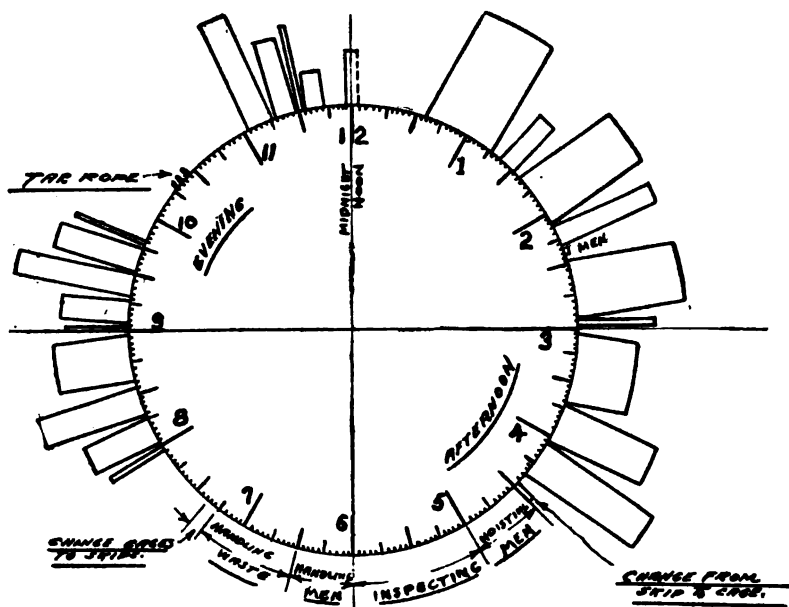


FIG. 2.—DIAGRAM SHOWING PRODUCTIVE WORK AT SPECULATOR SHAFT, NORTH BUTTE MINE.

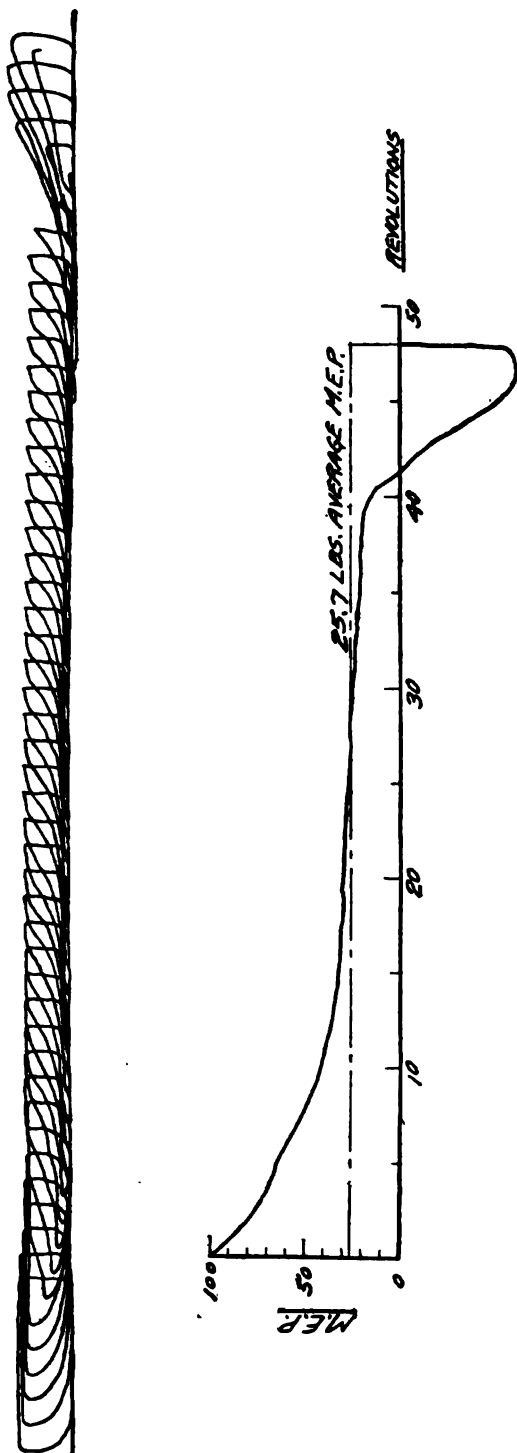


FIG. 3.—CHARACTERISTIC CARD WHEN HOISTING WITH A 32-32 BY 72 STEAM HOIST AT NORTH BUTTE MINE.  
BALANCED LOAD, 10,200 LB. OF ORE; LIFT, 1,800 FT.

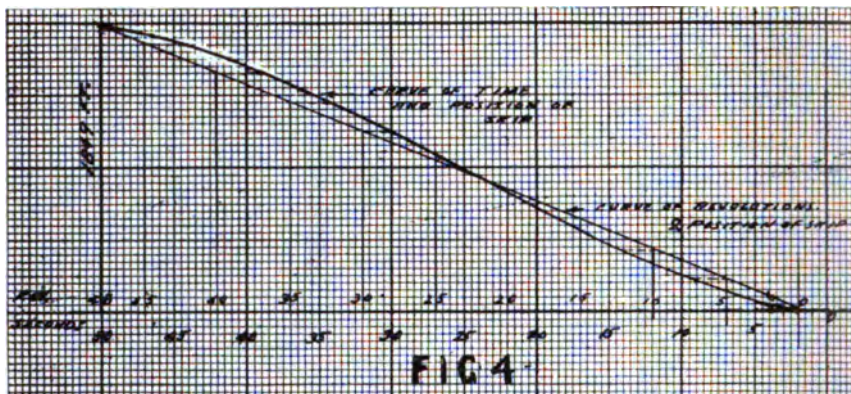


FIG. 4.—TIME-DISTANCE CURVE.



FIG. 5.—SECTION OF TACHOGRAPH CARD.

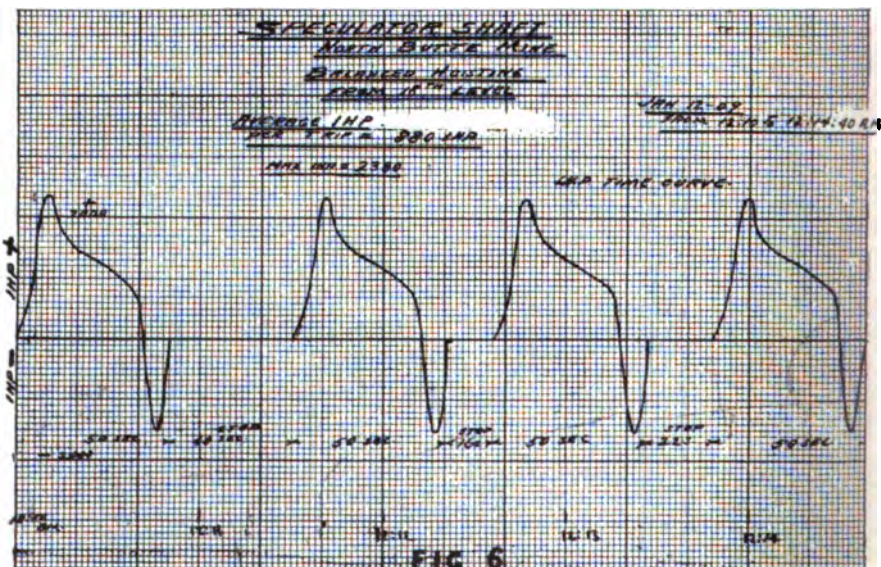


FIG. 6.—INDICATED HORSEPOWER TIME CURVE.



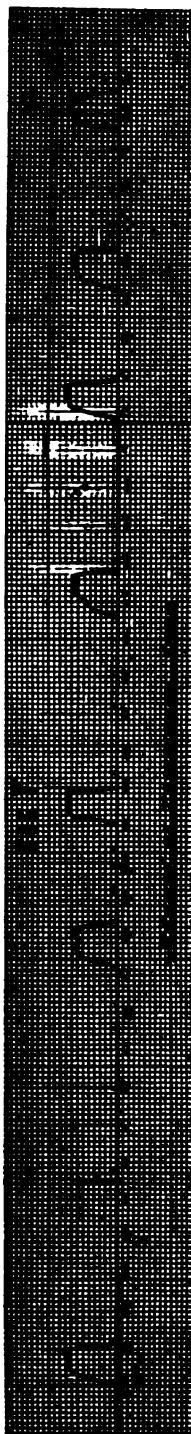


FIG. 7.—SECTION OF TACHOGRAPH CARD; HOISTING FROM 2,200-FT. LEVEL.

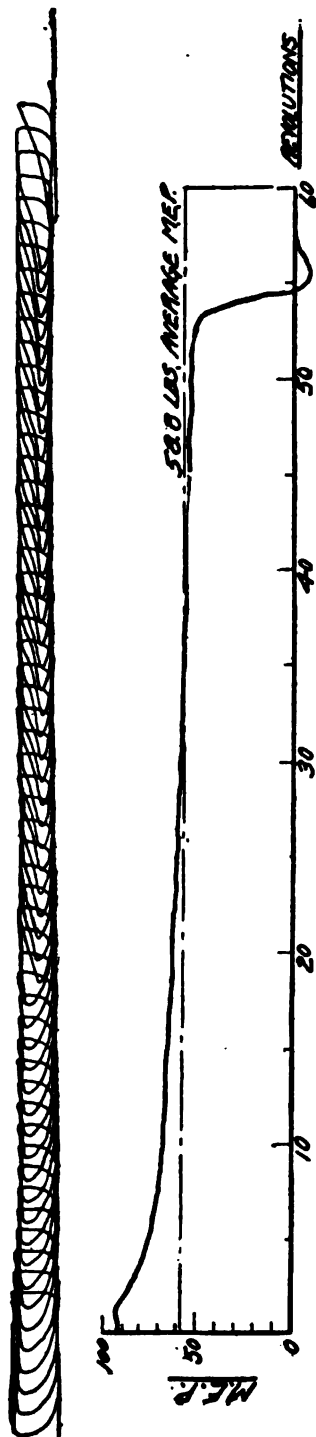


FIG. 9.—CHARACTERISTIC CARD WHEN HOISTING WITH A 32-32 BY 72 STEAM HOIST AT NORTH BUTTE MINE. UNBALANCED LOAD, 25,215 LB. OF ORE; LIFT, 2,200 FT.

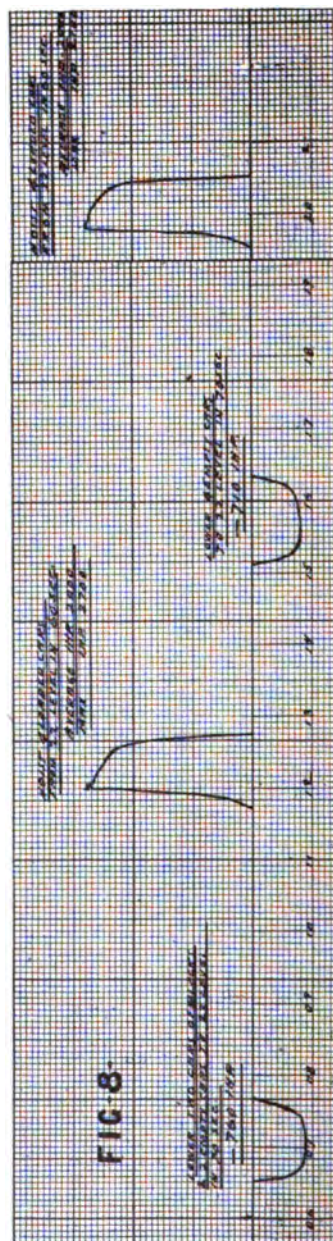
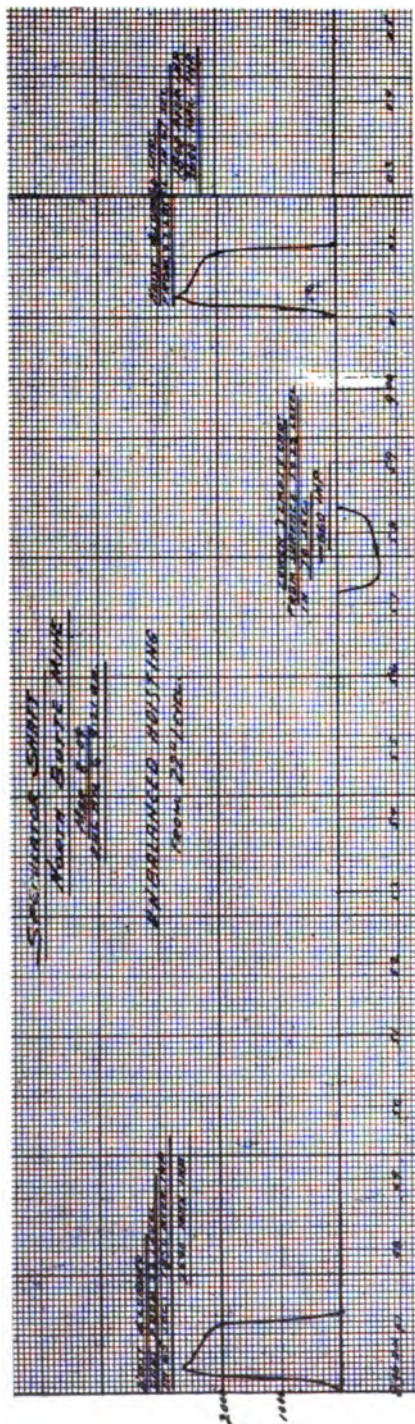


FIG. 8.—INDICATED HORSEPOWER TIME CURVE; HOISTING FROM 2,200-FT. LEVEL

This represents very nearly the average balanced hoisting condition at these mines.

From the diagrams of unbalanced hoisting from 2,200 ft. depth, Fig. 8 shows that during 34.5 min. the horsepower fluctuates from + 2,700 to - 900 h. p., the average during this period being 160 h. p. It has already been pointed out that most of the unproductive work is done out of balance. Occasionally a load averaging 2,000 i. h. p., with a peak 2,700 i. h. p. follows right after one averaging 900 i. h. p.

Much energy was also used in hoisting waste from lower to upper levels out of balance. In fact, it was found that although in all the large producers of the Butte mines an auxiliary hoist was installed to relieve the main hoist of non-productive work, still the non-productive and unbalanced hoisting performed with the main hoists covered fully as much, or more energy, than the productive work. That is largely due to the fact that most of the unproductive hoisting is done out of balance and that the "dead loads," i. e., ropes, skips and cages, are usually heavy. Thus, the skip and cage attached thereto at the Speculator shaft weighed about 11,000 lb. while the load in the skip was 10,000 lb.

The following table gives a good idea of the continuity of hoisting and the ratio of productive to non-productive work. The work done is expressed in effective horsepower: For 24-hr. run,

$$\text{Effective horsepower} = \frac{\text{Total W't hoisted (lb.)} \times \text{distance in ft. hoisted}}{\text{Total actual time (min.) hoist is in motion} \times 33,000}$$

*Effective Horsepower.*

|                 | Productive or Hoisting Ore | Non-Productive |          |                      | Ratio Prod. Work to Non-Prod. Work | Percentage of time during which hoist is doing positive work |
|-----------------|----------------------------|----------------|----------|----------------------|------------------------------------|--------------------------------------------------------------|
|                 |                            | Men            | Material | Total Non-Productive |                                    |                                                              |
| Speculator..... | 565                        | 433            | 758      | 1,191                | 1:2.12                             | 24.0                                                         |
| Diamond.....    | 706                        | 449            | 630      | 1,079                | 1:1.52                             | 19.6                                                         |
| High Ore.....   | 456                        | 713            | 813      | 1,526                | 1:3.34                             | 12.5                                                         |
| Mountain View.  | 508                        | 493            | 631      | 1,124                | 1:2.22                             | 21.6                                                         |

The power diagrams Figs. 6 and 8 are derived from the continuous indicator cards by measuring up every individual stroke diagram with a planimeter, determining the mean effective pressure, and, by aid of the time-depth diagram, ascertaining the time necessary to perform each revolution of the engine. From these quantities the indicated work expressed in horsepower was calculated for each revolution of the hoist and

plotted on time basis in the power diagrams. The diagram (Fig. 6) for balanced hoisting shows during the retardation periods a negative performance, i. e., the engine pistons during these periods did work upon the steam. This is the result of the practice in vogue of "plugging" the engines. To do this the valve motion is reversed at the commencement of the retardation period and the throttles kept partly open. The bypass is also kept partly open. The effect is then to retard the motion of the pistons with steam from the boilers, which steam escapes to the opposite side of the pistons and from there to the atmosphere as the exhaust valve is open on that side. The quantity of steam thus escaping and its pressure is regulated with the bypass valve. The continuous indicator cards show the retarding effect due to this mode of control, which results in the development of a negative work of nearly 1,000 h. p. during part of the retardation period. It is plain that the steam used when "plugging" is absolutely wasted, but as will be shown later on, an improved method of "plugging" was devised when these hoists were remodeled, by which the greater part of the energy used in retarding the hoists is returned to the power system.

It was found that the mechanical efficiency of these hoists varied greatly and that the friction was principally in the shaft guides and head sheaves. This was proved by the fact that in all cases the percentage of friction is much less when hoisting out of balance with one drum or reel held by the brake than when hoisting in balance. Thus we found that when hoisting from a depth of 2,200 ft., the friction of the hoisting engine, ropes, sheaves and cages, including the windage, was as follows:

|                 | In Balance.<br>Per Cent. | Out of Balance.<br>Per Cent. |
|-----------------|--------------------------|------------------------------|
| Speculator..... | 21.1                     | 13.0                         |
| High Ore.....   | 23.0                     | 17.5                         |
| Diamond.....    | 29.0                     | 10.0                         |

The friction was determined by hoisting a weighed load and taking continuous indicator diagrams while the load was hoisted. The friction is then the difference between the indicated work and that represented by the load hoisted 2,200 ft. The percentages given refer to the indicated work. There can be no doubt that the high values of friction found in some of the shafts are due to defects in the shafts and it is very probable that in some of the cases one compartment was more defective than the other. In the Diamond shaft, for instance, the compartment in which the unbalanced load was hoisted had free guides, while the cage did not run freely in the other one when the load was hoisted in balance. It is to be regretted that we did not in all cases test out the friction of both compartments of the shaft, in which case we would have been able to present more complete data on this subject.

In one of the shafts we found as high a friction as 40 per cent. of the indicated work. This shaft was, however, in bad shape at the time. All friction tests conducted on unbalanced hoisting gave consistent results, the lowest friction being obtained when hoisting at a low speed. The friction seemed to increase very considerably with the speed, which indicates that the effect of windage is greater than has been generally assumed. There are very few data available on friction of a mine hoist. Had we suspected, at the time we made our tests, what the results were to be we would have investigated the subject more fully. It is plain,

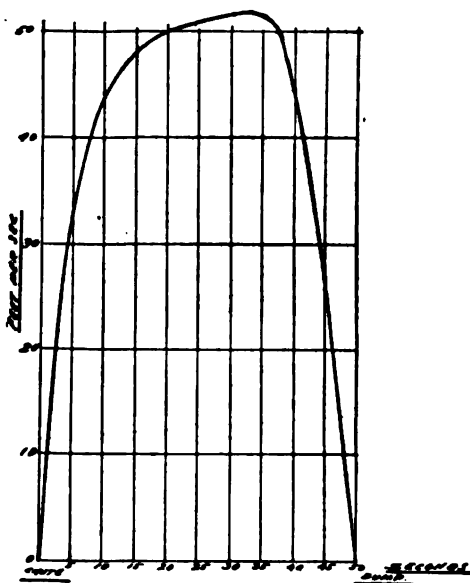


Fig. 10.—VELOCITY CURVE. BALANCED HOISTING FROM THE 18TH LEVEL OF THE SPECULATOR SHAFT, NORTH BUTTE MINE.

from the results obtained when hoisting out of balance, that the friction of the engine proper is a very small quantity, probably less than 6 per cent. in any of the engines tested.

Fig. 10 shows a rope speed curve when hoisting in balance from the 1,800 ft. level with a drum hoist. The load is hoisted in 50 sec. at an average rate of about 36 ft. per second, the maximum speed reaching about 52 ft. per second. The initial acceleration is about 8 ft. per second and the retardation about 5.6 ft. per second.

Fig. 11 shows the rope speed curve of the reel hoist at Diamond mine lifting the load in balance from the 1,800 ft. level. The load is here hoisted in 48 sec., so that the average speed is practically the same as in case of the drum hoist, but as the acceleration and retardation here average

only about 2.5 ft. per second, the maximum speed reaches as high a value as 72 ft. per second. The rope speed curve is here made up of the acceleration and retardation curves, meeting at the point of maximum velocity. This seems to be the characteristic of most flat rope hoists.

The foregoing shows that the hoisting is periodical in all these mines

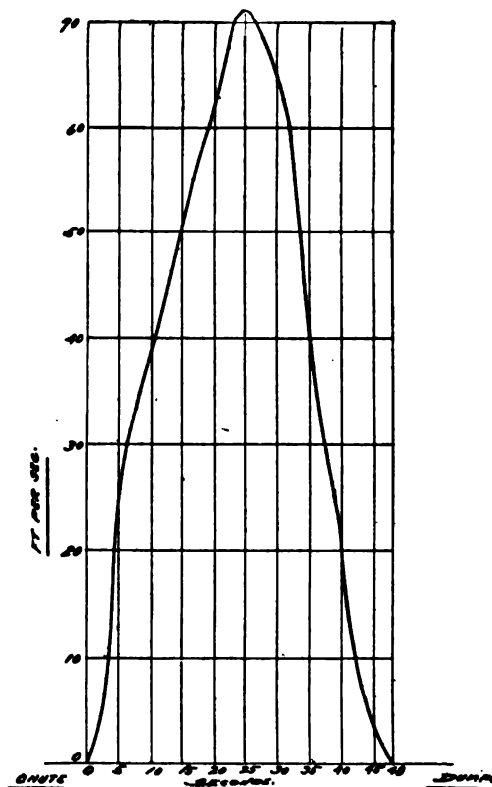


FIG. 11.—VELOCITY CURVE. BALANCED HOISTING FROM THE 1,800-FT. LEVEL OF THE DIAMOND MINE; 30-30 BY 72 REEL HOIST.

and done at a high rate of speed with high acceleration of the loads, the masses to be accelerated being excessively large.

The average of the work performed by the auxiliary hoists was in most cases found to be negative, i. e., the work done in lowering material into the mine exceeded that done in hoisting out of the mine. Thus, the positive work done in hoisting with the auxiliary at the Speculator mine was found to be 995,000,000 ft.-lb., while that done in lowering men, timber, tools, etc., was 1,073,000,000 ft.-lb. per twenty-four hours, making a total of minus 78,000,000 foot pounds per twenty-four hours.

In several mines, where large quantities of waste rock are lowered from

the surface down into the mine, the negative work performed is of such magnitude that if it could be recovered and the energy stored, a considerable saving would be the result. We shall show further on how this was accomplished.

Accurate records are available showing the work done and energy used by the steam hoists at the largest producing mines at Butte. It would take up too much space to exhibit these records in their complete form. The examples given above will, however, give a good idea of the magnitude and nature of the load to be handled by the Butte hoists.

When, in 1909, it was decided to operate these hoists by power, transmitted electrically to Butte, the question was discussed as to how much these existing hoisting conditions could be modified and improved. Any system of dispatching whereby the starting of two or more hoists simultaneously could be prevented was objectionable from a mining point of view. The periods of heavy hoisting, with corresponding periods of light or no hoisting, as illustrated by Fig. 2, could not be materially changed without seriously interfering with the underground operations.

It was then planned to regulate the hoisting so that these heavy periods would not coincide at all the mines as they did at that time. Up to the present time, however, this condition has not been changed materially.

Furthermore, the mining company desired the hoists not only to operate under the conditions already outlined for the steam hoists, but to possess considerable flexibility to allow for greater hoisting depths in the future and also for greater rates of production. After consideration of all these facts the Anaconda Copper Mining Company decided not to attempt to employ any method of operating the hoist by the application of electricity directly to them but to adopt the compressed air system of hoisting designed by the writer.

The power system for operating the hoists of the Anaconda Copper Mining Company mines comprises:

(a) An electrically operated air compressing plant in which air is compressed to 90-lb. pressure.

(b) The electric current is generated by water power located at a distance of 150 miles from Butte. In order that a maximum amount of energy can be transmitted through such long transmission line it is important that the work is perfectly equalized and all peaks in the load eliminated. This requires an air storage of great capacity and one in which the stored energy can be held without loss for extended periods.

(c) Air reheating plants at the different shafts.

(d) The hoisting engines were provided with new cylinders designed for economical use of the compressed air. The old and wasteful auxiliary hoists were replaced with new ones, specially designed for compressed air.

The air storage plant was connected with the rock drill system so that

during the idle periods when little or no air was used by the hoists, the air could be turned into the rock drill system.

At present upward of 25 per cent. of the total capacity of the compressor station is sent into the mine. This not only helps out the mine system but provides a high load factor for the compressor station.

### *Description of the Plant.*

\*The 100,000-volt substation at Butte is located near the center of the district in which the power is distributed. The substation building is 150 ft. by 50 ft. in plan and 50 ft. high. It is a brick-walled, steel-framed structure with concrete floors and roof.

There are installed at present two banks of single-phase transformers, rated at 3,600 kw. per bank and two banks rated at 7,200 kw. per bank, connected in delta on both high and low tension sides. They step the voltage down from 102,000 to 2,500, at which voltage it is distributed to customers. The transformers are installed in fireproof compartments, entirely shut off from the rest of the building by brick walls and opening only out of doors. The transformers are mounted on wheels and can readily be run out on to a flatcar which stands on a track running parallel with the building in front of the row of transformer compartments. This arrangement furnished a convenient method of handling the transformers, both at the time of installation and afterwards, in case it is necessary to make repairs.

On the gallery above the transformer compartments are located the electrolytic lightning arresters. On the gallery opposite are the 100,000-volt line switches. Possibly the most unique feature of the electrical layout is the 100,000-volt bus construction. For flexibility in switching, duplicate busses are provided. The busses themselves are made of 1.5-in. iron pipe suspended by standard line insulators from the roof trusses of the building. The three conductors of each three-phase bus are suspended one above another, each being supported by the next one above. The connections to the lines are also of iron pipe, making the bus structure as a whole quite rigid and well adapted to the use of suspension insulators.

The switchboard is in two sections, one section operating all line and transformer switches, which are remote controlled; the other section taking care of the 2,500-volt feeders, which are controlled by hand-operated automatic switches.

All electrical apparatus in the substation was supplied by the General Electric Co.

The load supplied in Butte is confined entirely to the mines, the power being used chiefly for the operation of motor-driven air compressors and electrically driven pumps.

*\*Substation—reprinted from an article by Max Hebgen in the "General Electric Review."*



The load is very nearly uniform for twenty-four hours each day throughout the year. The load factor is, in fact, close to 90 per cent.

### *Description of Compressor Station.*

In the compressor house which is located close to the substation there are installed six Nordberg two-stage compressors, three of which are fitted with variable capacity valve gear for automatically varying the capacity, while the other three run at a fixed capacity. The compressors are directly connected to Westinghouse synchronous motors and each compressor runs at a speed of 76 rev. per min. Fig. 12 shows an interior view of the compressor house. The cylinder dimensions of all compressors are 30 and 50 by 48 in. The pistons of these compressors are supported outside the cylinders, on crossheads running in oiled guides, the piston rods being very large in diameter so as to insure minimum deflection. Only the packing rings touch the cylinder walls. The variable capacity compressors have Corliss inlet valves and automatic discharge valves, the capacity being regulated by the closure of the inlet valves at different points of the stroke by means of a releasing mechanism under control of a pressure regulator. The constant capacity compressors are fitted with positively operated Corliss valves for inlet and discharge. These compressors show a high efficiency. A set of indicator cards from these compressors is shown in Fig. 13. The capacity of the compressors is at 76 rev. per min.—7,650 cu. ft. of free air per minute. The atmospheric pressure at the power plant is 12 lb. absolute and the normal air pressure 90 lb. gauge, or the same as used on the rock drill system, but when cards (Fig. 13) were taken the discharge pressure was 98.2. The indicated work is 1,099 h. p., while the theoretical work of perfect two-stage compression with perfect intercooling and no pressure losses is 1,045 h. p. referred to the actual air compressed.

As the starting of these compressors, if done by the electric motor in the ordinary way, would throw peaks of considerable magnitude upon the electric system, a new method of starting was adopted whereby such peaks are entirely avoided. The valve motion of the compressors was fitted with a reversing gear whereby the valves, for the purpose of starting, are so adjusted as to turn the machine into an air motor. In the Butte power system there is always a large volume of air stored and maintained under 90 lb. pressure. The compressors are thus started and brought up to speed by the energy in the stored air. When up to speed and in synchronism with the generators 150 miles away and with other compressors running, the electric current is switched on and valve motion reversed. The machine immediately starts to compress air. Thus, when starting no electricity is used and when the air compression begins with the com-

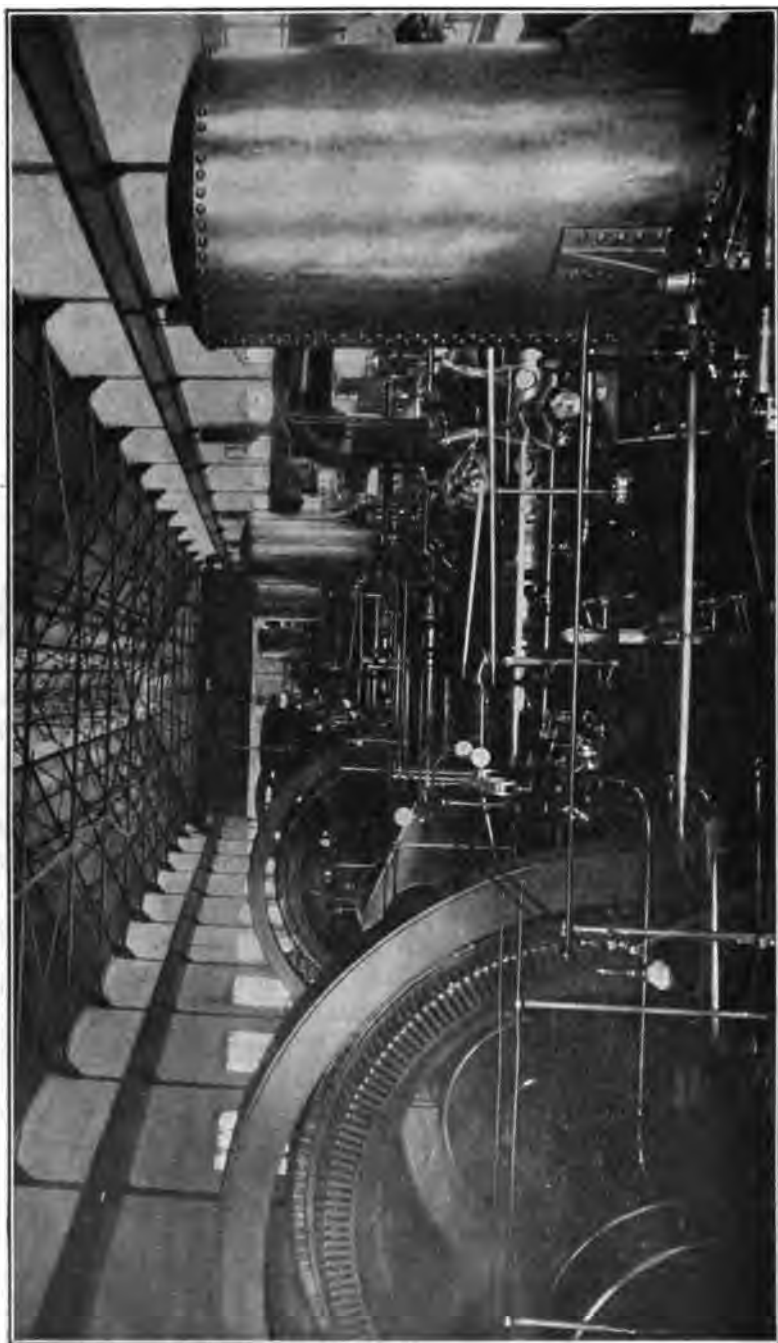


FIG. 12.—INTERIOR OF COMPRESSOR PLANT SHOWING RECEIVER.

pressor up to speed and in synchronism, the power is only the normal power necessary for the compression. This starting gear works very satisfactorily. At the end of April and beginning of May, 1912, Butte was visited by several severe electric storms which caused interruption in

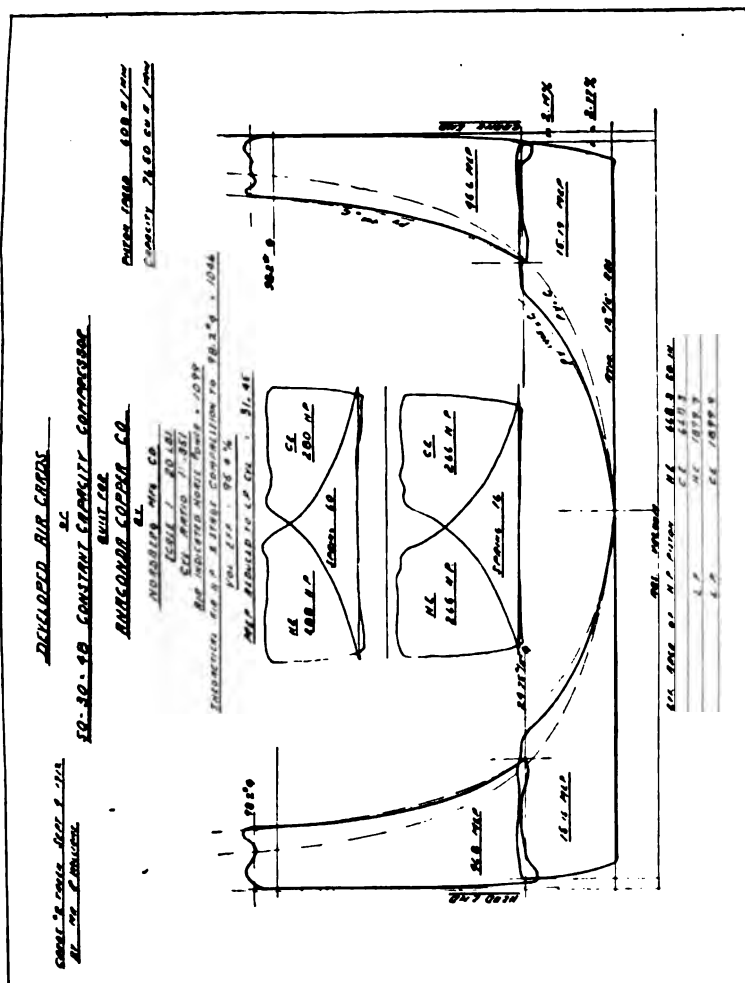


FIG. 13.—DEVELOPED AIR CARDS. CONSTANT CAPACITY COMPRESSOR.

the operations of the compressors several times. At that time there were four compressors installed, three running and one in reserve. On May 2, 1912, during a particularly severe storm, all three compressors were stopped by lightning. The shutdown was not of long enough duration to interrupt the hoisting, and the time required to start the three compressors was less than four minutes from the moment when the first



FIG. 14.—VIEW OF VARIED CAPACITY COMPRESSOR.



FIG. 15.—VIEW OF CONSTANT CAPACITY COMPRESSOR.

compressor started until all three were in step, reversed and compressing air into the system.

The compressors are connected to a number of large air receivers and these to the distributing main in a manner as shown in Fig. 17, from which can be seen that any of the receivers can be shut off from the system for inspection or repairs, there being a valve on each side of the receiver for that purpose. Figs. 14 and 15 show respectively the variable and the constant capacity compressors.

### *Air Storage.*

In order to equalize the load on the compressor station, it was necessary to provide for two kinds of peak loads on the hoists, first—the peak due to the acceleration of any hoist. These peaks are very large but last for a few seconds only. To take care of this condition, storage receivers of sufficient capacity to liberate sufficient air for the acceleration of the hoist without excessive pressure drop were installed at each hoist. The highest rate of air consumption at the large hoists is at the rate of about 60 cu. ft. of compressed air per second for 5 sec. This condition determines the air receiver capacity necessary, each requiring four receivers of 2,100 cu. ft. volume. It will be readily understood that as the pipe lines from the compressors to the different hoists on the system are of considerable length that the capacity of the pipe lines are of little value as storage reservoirs unless accompanied by a prohibitive pressure drop. The installation of the above receivers therefore allows the pipe lines to be designed for average flow.

The amount of energy that can be stored in the receivers or expansion tanks is, however, limited. Calling the volume of compressed air supplied to each receiver during any given length of time  $v$ , the volume drawn from the receiver by the hoist during the same time  $v_1$ , and the volume of the receiver  $V$  gives us

$$V = \frac{v_1 - v}{1 - r} \text{ and } r = \frac{V}{V + (v_1 - v)}$$

if  $r$  is the ratio of the final to the initial pressure in the receiver during the same time.

During the acceleration period when the maximum rate of air consumption may reach 60 cu. ft. per second for 5 sec.  $5 \times 60 = 300$  cu. ft. for 5 sec., we get, if air is supplied to the receiver at the rate of 15 ft. per second, under which condition there is no appreciable drop of pressure in the pipe line:

$$V = 4 \times 2100 = 8400 \text{ cu. ft.} \quad v = 5 \times 15 = 75 \text{ cu. ft.} \quad v_1 = 300 \text{ cu. ft.}$$

$$v_1 - v = 275.$$

$$r = \frac{8400}{8400 + 275} = \frac{8400}{8675} = 0.97$$

so that, if the initial pressure in receiver is  $90 + 12 = 102$  lb. absolute, the final pressure will be  $102 \times 0.97 = 99$  lb., or the pressure drop 3 lb. As the air in the pipe line is accelerated during the acceleration period of the hoist, and therefore attains a higher rate of speed than 15 ft. per second, the pressure drop during the period will actually be less than 3 lb. The pipe lines are made of such diameter that they will allow a flow of 2,700 cu. ft. of compressed air per minute or 45 cu. ft. per second with a pressure drop of 5 lb. The heaviest unbalanced loads call for an air consumption of 40 cu. ft. per second and as they are hoisted in one minute of time, 2,400 cu. ft. of compressed air will during that time flow into the hoist cylinders.

The pressure drop will, therefore, be less than 5 lb. as less air is taken out of the receiver than can be supplied to it from the pipe line with 5 lb. drop.

Each of the large hoists is fitted with four storage receivers aggregating 8,400 cu. ft. capacity and there are similar receivers installed at the compressor plant. As all these receivers are connected by the pipe lines they will act together in case of any heavy demand of air, no matter if this air is demanded at one hoist or at several hoists simultaneously. In order to show in how far remote these receivers can equalize the demand for power if heavy hoisting is going on simultaneously in several mines, we will assume that in three of the largest producers hoisting is in progress from 1,800 ft. depths and that in each 36 loads are raised in 36 min. This is a condition that actually exists and must be met, and each trip requires 1,012 cu. ft. compressed air. Three compressors are running, each supplying 880 cu. ft. compressed air per minute, or 2,640 cu. ft. per minute for the three.

There are at the different mines connected to the system 40 air receivers and on the compressors 12 receivers, or a total of 52 receivers, each of 2,100 cu. ft., so that the aggregate receiver volume will be  $52 \times 2,100 = 109,200$  cu. ft. We have thus:

$$v = 2640 \times 36 = 95040$$

$$v_1 = 1012 \times 3 \times 36 = 109296$$

$$V = 109200$$

$$r = \frac{V}{V + (v_1 - v)}$$

$$v_1 - v = 14256$$

$$r = \frac{109200}{123456} = 0.886$$

At the end of the 36-min. period there is thus a pressure on the system of  $102 \times 0.886 = 90$  lb. absolute. The air pressure has then dropped 12 lb. during that time. From the above can be seen that air receivers placed in the pipe line are not very effective when it is required to store much energy. Such receivers can liberate only a limited volume of air =  $V\left(\frac{1}{r} - 1\right)$  depending on the drop of pressure. In the foregoing example the receiver volume was 109,200 cu. ft., with a 12-lb. drop and 90 lb. initial gauge pressure the volume of air liberated is

$$= V \times \left( \frac{1}{0.886} - 1 \right) = V \times (1.113 - 1) = V \times 0.113$$

or only a little over 11 per cent. of the receiver volume.

In this respect the action of such air receivers (expansion tanks) is identical with that of a flywheel in an Ilgner transformer. In both cases only part of the stored energy can be liberated. There is, however, no loss incurred when storing energy in the form of compressed air if the receiver is tight, while in case of a fast running flywheel considerable power has to be consumed to overcome friction and windage, which power is absolutely lost. The action of the flywheel in this respect is similar to that of a leaky air receiver from which there is a constant leakage of such magnitude that, if filled with air, the air would in a few minutes be lost. An illustrative example of this will be given further on.

The foregoing shows how the instantaneous peaks, due to acceleration of hoists, were taken care of, but in addition to these instantaneous peaks there were longer peaks due to rapid periods of hoisting as illustrated by Fig. 2.

In order to get an idea of what peaks would arise from such conditions the writer estimated that if all the mines of the Butte district were connected to the power system and operated with compressed air, and if the operation could be so regulated that the periods of high air consumption would not overlap each other at the different mines, the resultant air consumption would be as per diagram Fig 16. This diagram is based upon investigation at different mines in the year 1909 and includes 27 hoisting engines of various sizes and capacities. According to this chart the highest rate of air consumption would be 37,200 cu. ft. free air per minute, and the average, 27,660 cu. ft.<sup>1</sup>

<sup>1</sup> It can be seen from this chart that there are 10 peaks in the air consumption curve above the average and 10 depressions. The different peaks and depressions are in reality, the average of a great number of peaks and depressions of very great magnitude, resulting from the simultaneous acceleration of several hoists and simultaneous periods of short duration during which the air consumption is very low. Some of these peaks figure as high as 100,000 cu. ft. of free air per minute during a few seconds of time. Such air consumptions, as have been stated before, are taken care of by the expansion tanks.



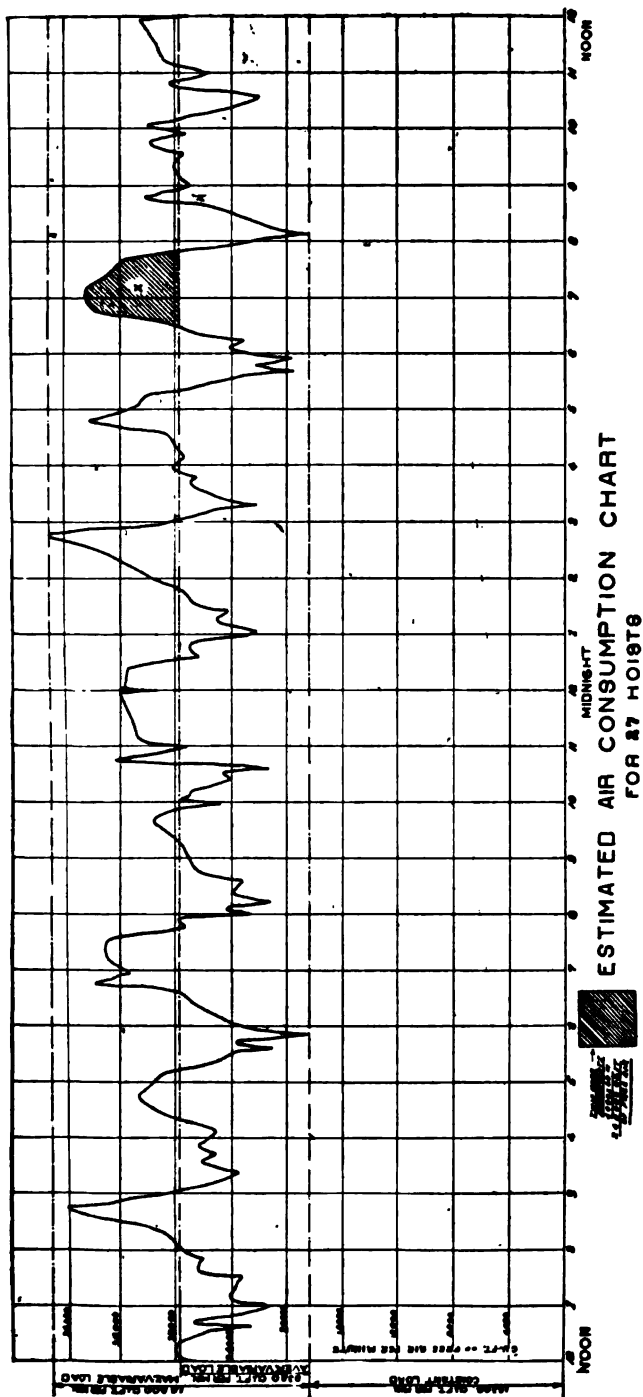


Fig. 16.—ESTIMATED AIR CONSUMPTION CHARTS.



FIG. 17.—OUTSIDE OF COMPRESSOR PLANT.

This chart can be considered to represent the most favorable distribution of the work with minimum peaks in the air consumption. The largest peak (X) in the diagram represents a volume of 44,000 cu. ft. of air



FIG. 18.—HYDROSTATIC TANK.



FIG. 19.—HYDROSTATIC AIR RECEIVERS.

at 90 lb. pressure and gives the measure of the minimum storage capacity required in order to equalize the load on the system. The energy represented by this peak is about 1,060,000,000 foot pounds.



To provide for this peak of 44,000 cu. ft. capacity with expansion tanks would mean that with a pressure drop of 10 per cent. ( $v=0.9$ ) we would then have  $(v_1-v)=44,000=V(\frac{1}{r}-1)=0.1V$  or  $V=440,000$ . Such a storage receiver would be prohibitively large.

If, therefore, a uniform load on the electric motors operating the hoisting engines is aimed at, most of the energy used must necessarily be stored energy; hence, the storage device must not only have great capacity, but must also retain the stored energy without loss. A body of water located at a certain elevation above a suitable motor would be an ideal device for storing power. The whole potential energy of it would be available for generating power, and as long as the reservoir and its connections are tight, the energy can be kept in storage for an indefinite period of time.

The hydrostatic storage plant forming part of the Butte power system consists of a number of air receivers connected so the whole forms a receiver of about 66,000 cu. ft. capacity. Some 210 feet above these receivers there is an open water tank 100 ft. in diameter. A pipe leads from the bottom of this tank to the bottom of the air receivers. Air from the compressor plant is piped to the top of these air receivers. Fig. 20 is a general drawing of this plant. Water is run into the elevated tank until the lower tanks and the rising main are filled up to the bottom of the elevated tank. When air is compressed into the lower tanks it drives the water out, and when 66,000 cu. ft. of compressed air have been pumped into these tanks the water is out and nearly fills the upper tank. A long return bend is formed in the water pipe, which bend runs down hill for a considerable distance, so that, if the water is driven out of the air receivers, the air pressure will have to rise very materially before it can force the water out around the bend and before air could enter the water pipe and blow out into the upper tank.

Fig. 18 shows the open tank on top of hill with the substation and compressor house in the background, and Fig. 19 shows the hydrostatic receivers at foot of the hill.

The diagram in Fig. 21 illustrates the capacity of this storage system. When the air receivers are full of air and all the water is in the upper tank we have stored up 66,000 cu. ft. of water under a head of 210 ft. The potential energy of this water is 865,141,200 foot pounds and is represented in the diagram by the shaded area *A*. In addition to this there is available for power the expansion force of air at 90 lb. pressure represented by the shaded area *B* in the diagram, the potential energy of which is 730,179,000 foot pounds. We have thus in this plant a total capacity of storage of 1,595,320,200 foot pounds.

It may be of interest to compare the capacity of this storage plant with other devices used for the same purpose. Thus we have shown that air

receivers placed on the compressed air pipe line system and liberating energy by drop of pressure, will with 12 per cent. drop in pressure liberate about 11 per cent. of the volume of air contained in such receivers.

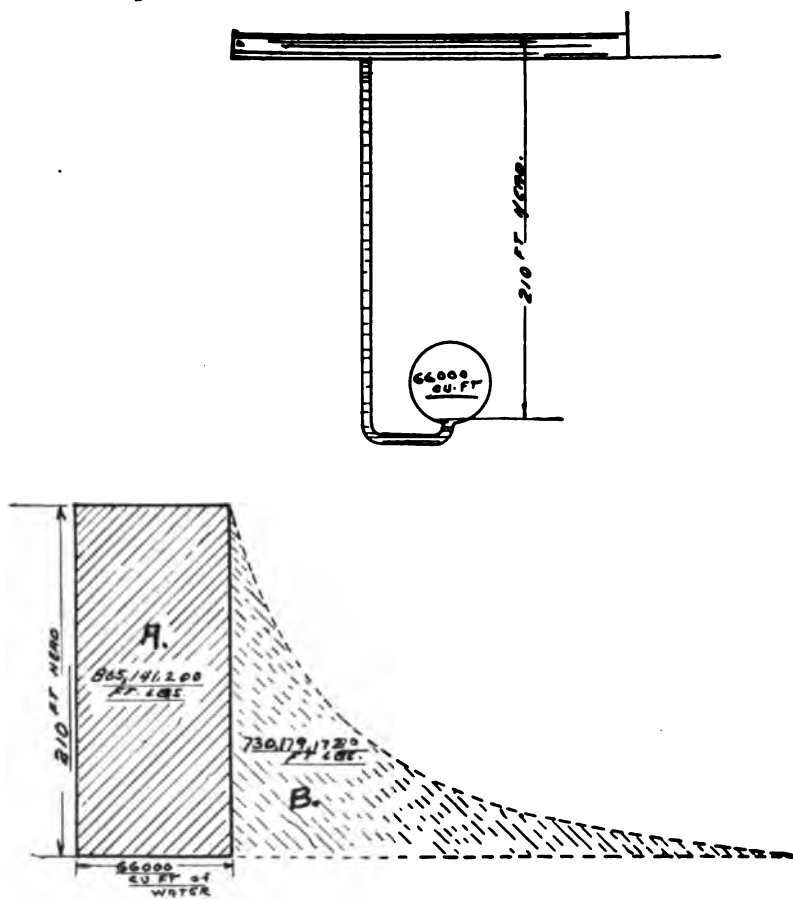


FIG. 21.—DIAGRAM SHOWING HYDROSTATIC SYSTEM.

In order, therefore, to liberate 66,000 cu. ft. of air, the receivers should have a volume of

$$\frac{66000}{0.11} \text{ or } 600,000 \text{ cu. ft.}$$

The flywheel transformers used at the Matthias Stinnes Mines at Essen, in Germany, and which are among the largest built so far, have two flywheels weighing 44 tons each and running at a rim velocity of about 17,000 ft. per minute maximum. In delivering power the speed is allowed to drop about 18 per cent. The maximum speed is about 284 ft.

per second. The radius of gyration of these wheels is about 0.8 of the radius of outside of rim, so that the masses of the wheels act with a maximum velocity of  $0.8 \times 284 = 227$  ft. The energy of the revolving wheel at full speed is thus:

$$\frac{2 \times 88000}{2 \times 32.17} \times 227^2 = 140,000,000 \text{ ft. lb. approximately.}$$

A drop of speed of 18 per cent. brings the minimum velocity at radius of gyration down to  $0.82 \times 227 =$  about 186 ft. per second. The potential energy in the wheel at that speed is thus:

$$\frac{2 \times 88000}{2 \times 32.17} \times 186^2 = 94,000,000 \text{ ft. lb. approximately.}$$

The available energy stored is thus  $140,000,000 - 94,000,000 = 46,000,000$  foot pounds. The statement was made to the writer at the mines that it required over 300 h. p. to keep up the full speed on this apparatus when running idle, 240 h. p. would then be a safe estimate of the average power if the speed drops 18 per cent.

240 h. p. is  $240 \times 33,000 = 7,920,000$  foot pounds per min., dissipated energy, so that the whole amount of stored energy would be lost in

$$\frac{46000000}{7920000} = 5.8 \text{ minutes.}$$

George McCulloch, in his book on winding engines, states that the Ilgner transformer at the Deutscher Kaiser Mine requires 95 kw. to run idle. This transformer is said to have a 46-ton wheel running 370 rev. per min. The rim speed is not given but it is stated that the maximum kinetic energy of the wheel is 81,600,000 foot pounds. The power required and the energy of the wheel are nearly in proportion to that given above for the larger transformer at the Matthias Stinnes Mines. In that case it was found that about one-third of the total maximum energy could be liberated. Let us assume that in case of the transformer wheel at the Deutscher Kaiser we also can liberate one-third of the maximum energy or about 28,000,000 foot pounds of work. The power to keep up the full speed was in this case 95 kw. or an average of 77 kw. if this speed drops 18 per cent.

$$= 77 \times 44,240 = 3,400,000 \text{ foot pounds per min.}$$

The stored energy is thus dissipated in  $\frac{28000000}{3400000} =$  about 8.25 min.

A compressed air storage of any type is not subject to leaks of such magnitude and is therefore better adapted to the conditions of hoisting as they exist in most ore mines where the work is irregular and the load factor very low. The storage system used in Butte is no doubt the best as the whole energy stored can be drawn upon. At Butte the air receivers

forming part of this storage had to be made of steel. In many localities the air receiver can be built into the country rock and in that case even a much larger volume of air can be stored than in the plant described above. Mr. MacNaughton is now constructing an underground air storage receiver at the Cahumet & Hecla Mine which will have a volume of 252,000 cu. ft. It will be nearly four times as large as the Butte air storage plant. With a 10 per cent. drop of pressure ( $r = 0.9$ ), such receiver will liberate  $252,000 \times 0.1 = 25,200$  cu. ft. of compressed air. It will be the largest air storage receiver thus far built in the world.

A test was made two years ago to determine the efficiency of the Butte air storage system. The storage system was filled with air and the compressor stopped. The Mountain View hoist was then run for an hour *with stored energy*, hoisting regular loads of 5 tons in balance. 21 skips were hoisted from a depth of 1,870 ft. and 16 skips from 1,570 ft. depths. The drop of the water level in the 100 ft. tank was then measured. Then the compressor was started and the air drawn from the system during the run, which was of one hour's duration, was restored.

The electrical input to compressor for restoring the air was ascertained. Indicator cards were taken during the run, which showed a very low mechanical efficiency of the combined engine and hoisting gear, due to the fact that the Mountain View shaft was crooked, causing binding of the skips. The mechanical efficiency was here only 69 per cent. when hoisting from 1,870 ft. and 57 per cent. hoisting from 1,570 ft. depths.

The result of the test was that 327 h. p. at this shaft required an electrical input to the motor of compressor of 836 kw. or 2.56 kw. per shaft h. p. Correcting this for the excess friction of the Mountain View shaft over that found by test at the High Ore and Speculator shafts, in both of which the mechanical efficiency of the hoisting engines and skips was about 80 per cent., we get an input of 2.04 kw. per shaft h. p.

This test was made with very moderate heating of the air (air temperature  $258^{\circ}$ ) and the retardation at the end of each run was done by "plugging" the engine in the old way and not by compressing air back to the system.

#### *The Air Heaters.*

The air reheaters on this power system are of an indirect type, in which steam of 200 lb. pressure is used as the heating medium. In nearly all of the mines there is a steam heating plant for the dry house. The small boiler that furnishes steam for the air heater is placed in the boiler house with the boiler for the dry house and one fireman can take care of both. In most cases the air heater is located at a higher elevation than the boiler house so that the water of condensation from the air heater runs by gravity back to the boiler as soon as it is formed.



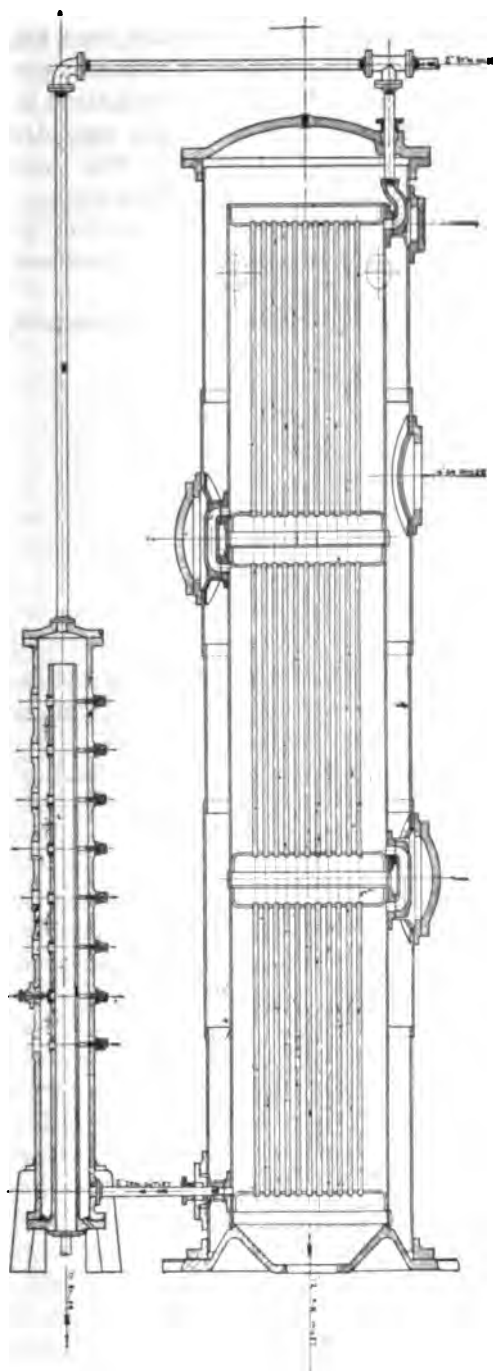


FIG. 22.—DETAIL OF AIR HEATER.

Fig. 22 shows a section of the air reheater, and Fig. 23 the manner in which it is connected to the boiler. The heater consists of an outer vertical cylinder in which are placed three cylindrical shells closed at the ends by tube heads. A number of tubes are expanded into these tube heads, which tubes run through the shells. The three (3) inner shells are mounted one above the other, the lowest one resting on a ledge formed in the outer cylinder. The air enters at the bottom, passes through the tubes of the inner shells and sweeps over the outer surface of the upper

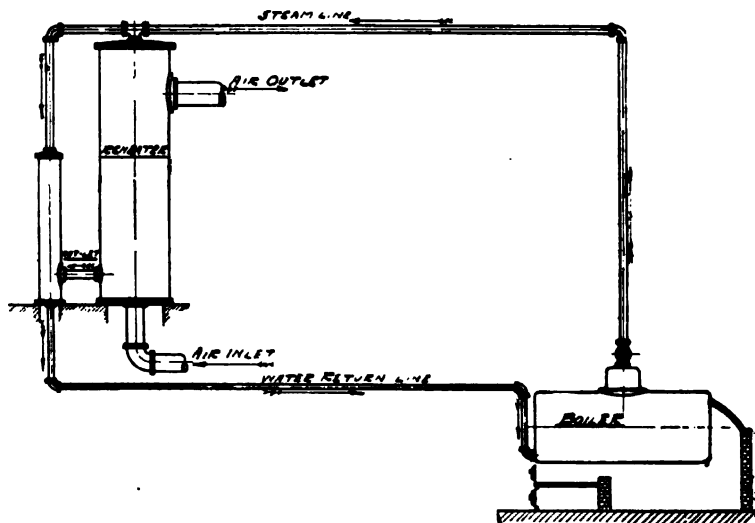


FIG. 23.—SYSTEM FOR REHEATING AIR.

one of these inner shells before it passes out of the heater. The inner shell is filled with steam of 200 lb. pressure which surrounds the tubes. The steam enters the upper one of the inner shells near its top. Balancing pipes are fitted between the bottom of the upper and top of the middle shell, and between bottom of this and top of lower shell. The water formed by condensation leaves the lower shell at the bottom. It has been found that the water of condensation is a very efficient medium for transmitting heat to air, in fact, more efficient than the steam. It is, therefore, important to regulate the water level so that the temperature of the outgoing water is a minimum. For this purpose the heaters are provided with a water column inside of which is a vertical pipe connected to the water discharge on the lower inner shell of the heater. There are several openings at different heights in the vertical pipe, perforating its walls and provided with stop valves so that any of these openings can be closed. At the lowest point of the outer pipe, or water column, is the discharge nozzle which is piped to the boiler. By closing the dis-

charge holes in the inner pipe in succession, beginning with the lowest one, the water level in the inner heater shells can be elevated to the desired point.

### *The Hoisting Engines.*

The largest producing mines in the Butte district are the following:

|               |              |
|---------------|--------------|
| Mountain View | West Stuart  |
| High Ore      | Pennsylvania |
| Diamond       | Tramway      |
| Original      | Leonard      |

Of these the Mountain View, High Ore and Diamond use flat ropes and reels; the others use 12 ft. drums with  $1\frac{1}{2}$ -in. round ropes. The power requirements of the different mines of this group are very nearly identical. As these engines were in good condition, and of ample strength in all parts, the only change necessary for adapting them to the economical use of compressed air was in the cylinder construction and the operating gear.

At each of these mines and also in other mines operated by the Anaconda Copper Mining Co. there were auxiliary hoists, several of which did more lowering than hoisting. These smaller hoists were discarded and replaced with new ones so designed that the downgoing load compresses air and returns it to the storage plant. 12 new hoists with cylinders 28 in. by 48 in. and 6 ft. drums were built, four of which were provided with double clutched drums. All these hoists have a winding capacity of 3,500 ft.

Figs. 24 and 25 show one of the new air cylinders fitted to the main hoists. Nine sets of such cylinders were made, all being 34 in. diam. by 72 in. stroke. Fig. 26 gives a view of the single drum auxiliary hoists, and Fig. 27 gives a view of the double drum auxiliary hoist. These views were taken at the works of the Nordberg Mfg. Co., where the machinery was built.

I think that this machinery is the first attempt to build large air motors designed to use compressed air, so as to approach the efficiencies that theoretically should result when air is compressed, heated and expanded. Theoretically one cubic foot of free air at the atmospheric pressure at Butte requires 4,356 foot pounds of energy for compression to 102 lb. absolute, or 90 lb. gauge pressure if the work was done in a perfect 2-stage compressor. The total mean effective pressure of this process is 30,248 lb. per sq. in. The temperature of air discharged from this compressor is 250° F. if the initial temperature is 60° F.

A perfect two-stage compressor is one without clearance and without pressure losses. The air is cooled to the initial temperature (say 60° F.)

before entering high-pressure cylinder. The cylinders are so proportioned that one-half of the work is done in each.

If the heat of compression is lost so that the temperature of the compressed air drops back to the initial temperature of  $60^{\circ}$  and the air be expanded without taking up heat in a cylinder to atmospheric pressure, a work of 2768.5 foot pounds is performed. The efficiency of the process is, therefore, 63.5 per cent.

By heating the air before expansion and thereby increasing its volume, the air can be made to perform more work and the efficiency will be in-

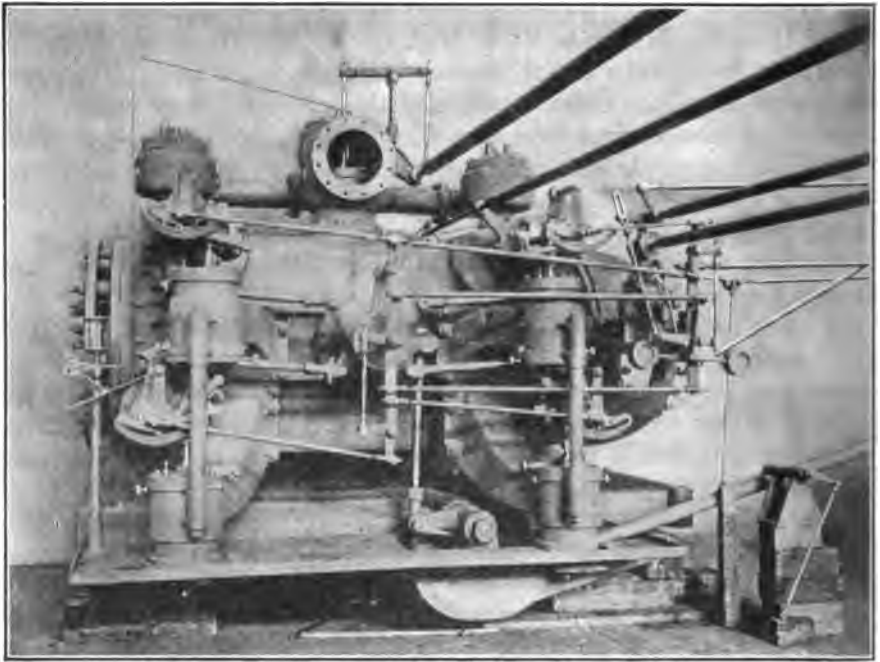


FIG. 24.—CYLINDER FOR AIR HOIST.

creased. If the air was heated to  $507.3^{\circ}$  F. it would perform 4,356 foot pounds of work or just as much as was required for its compression. The efficiency would then be 100 per cent.

To obtain 100 per cent. efficiency under above conditions would cost 0.08 c. per h. p. per hour if the fuel (coal) was worth \$4 per ton, containing 12,500 B.t.u. per pound and the efficiency of the air heater was 60 per cent.

If the assumed quantity of air (1 cu. ft. at atmospheric pressure and  $60^{\circ}$  F.) after compression was expanded in a two-stage motor with cylinders displacing the same volume of air per unit of time, as the compressor,

the work done in such a motor would be exactly the same as that required to compress the air, if the air entered both cylinders of the motor with a temperature of  $250^{\circ}$  F. The motor would therefore require an interheater between high and low pressure cylinders and a preheater if the heat of compression was lost. By such a process 100 per cent. efficiency is obtained with only  $250^{\circ}$  air temperature and at an expense of 0.068 c. per h. p. per hour.

In the above it is assumed that there is no loss of pressure between the compressor and the motor. Should there be a drop of 15 lb. between the

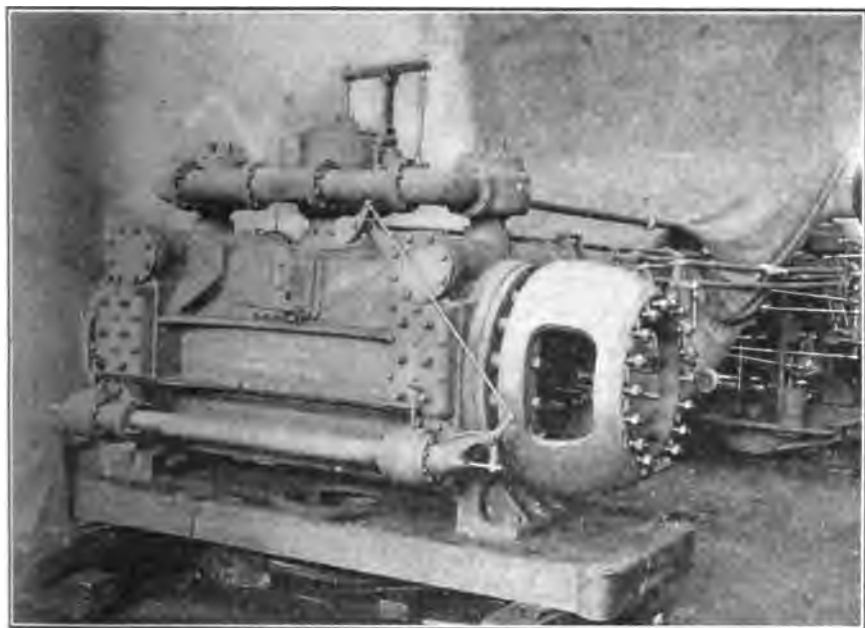


FIG. 25.—CYLINDER FOR AIR HOIST.

discharge pressure of the compressor and the initial pressure on the motor, we would, in case of a two-stage motor, have to heat the air before entering the high pressure cylinder to a temperature of  $263.4^{\circ}$  F. and to  $289^{\circ}$  F. before entering the low-pressure cylinder. The air will then be exhausted at a temperature of  $94.9^{\circ}$  from the low-pressure cylinder, which is  $34.9^{\circ}$  higher than the initial temperature of compression. The cost of reheating in this case will be 0.073 c. per h. p. per hour if the efficiencies and fuel cost and quality are as assumed above.

The air pressure in a power system at a mine is for practical reasons determined by that used on the rock drills. At Butte this pressure is 90 lb. From the above it follows that by reheating the air, the largest

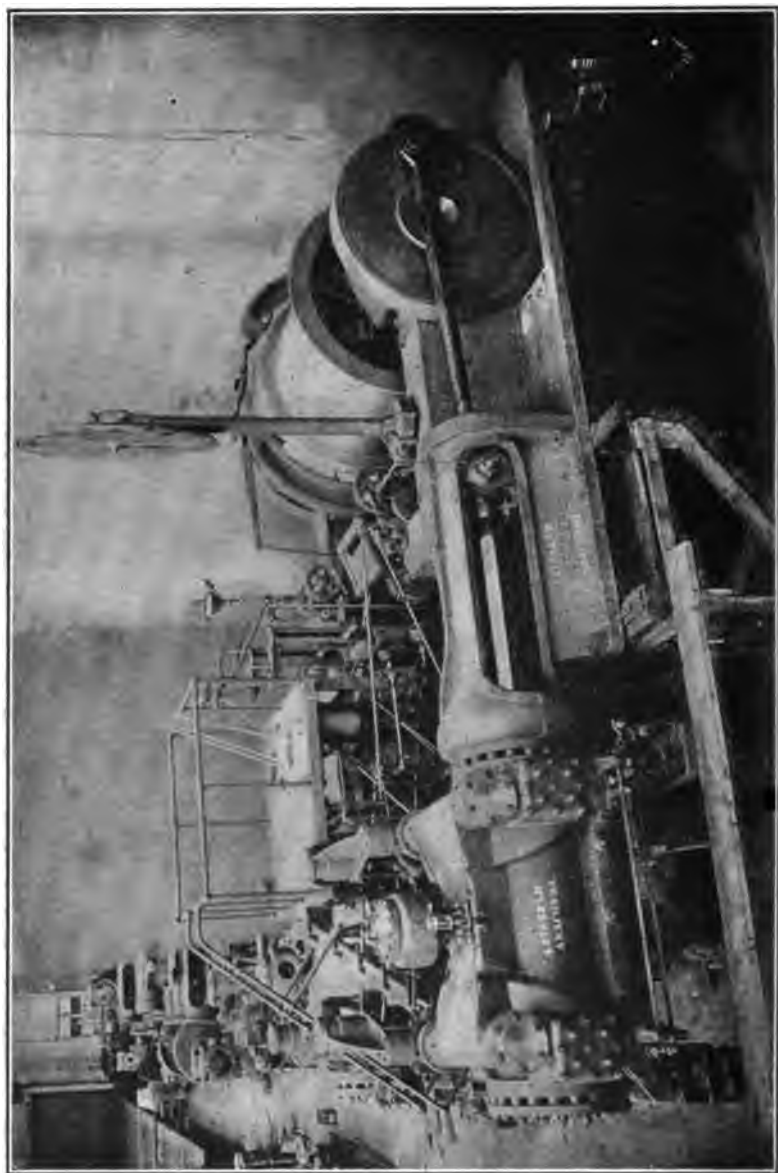


FIG. 26.—GENERAL VIEW OF AIR HOIST.



FIG. 27.—GENERAL VIEW OF AIR HOIST.

possible gain in efficiency is 36.5 per cent. and it will be noticed that the expense in fuel for gaining this efficiency is quite a small item.

In order to obtain maximum efficiency on the air-operated engines there must be no drop of pressure between the compressor and the engine, the engine must have no clearance, the air must always be expanded to the atmospheric pressure and the cut-off should be abrupt so there is no wire drawing.

The pressure drop can, with proper pipe lines, and receivers such as are used in the Butte plant, be kept inside of 10 per cent. of the initial pressure.

The clearance in an air motor, the piston speed of which runs up to nearly 1,000 ft. per minute, as is the case with the long stroke hoists at Butte, will of necessity be large, as such engines require large valve ports, much larger than a steam engine at the same speed, for the reason that the compressed air has a greater density than steam of the same pressure. If, however, the exhaust valves are made to close early enough during the return stroke of the piston to compress air to a pressure equal to that at the admission, then the effect on the efficiency of the clearance space, no matter how large it may be, is entirely eliminated. In a hoisting engine the compression would make it impossible to maneuver at slow speed. To overcome this the Butte hoists have a valve gear so designed as to automatically adjust the closure of the exhaust valves to compress to initial pressure as soon as the engine has attained a high enough speed to safely carry such compression, and to automatically remove the compression when the engine drops below this speed. We have, therefore, in the Butte hoists no clearance loss except when running at slow speed. The clearance loss, if present, would result in a reduction of efficiency of about 25 per cent.

If the load on an air motor and the air pressure was absolutely constant, then the cylinder dimensions could be so proportioned that the cut-off takes place at the exact point expanding from which the terminal pressure coincides with that of the atmosphere. In a cylinder without clearance this point of cut-off would be about 22 per cent. of the stroke if the absolute pressure of the atmosphere is 12 lb. and the air pressure 90 lb. above the atmosphere. In a cylinder with clearance the cut-off takes place earlier in the stroke to fulfill this condition. At any other point of cut-off there is a loss of efficiency. A later cut-off than 22 per cent. produces incomplete expansion. In this case the air is exhausted from the cylinder at a pressure higher than that of the atmosphere, causing a waste of energy which, if the cylinder were allowed to take air at full stroke, reaches a maximum of about 50 per cent. of the total energy in the compressed air. If the cut-off is earlier than 22 per cent., the air will expand below the atmosphere, producing "loops" in the indicator cards. Such "loops"



are areas of negative work and as air expands adiabatically, the pressure during expansion dropping at a much greater rate than the volume swept by the piston increases, these areas of negative work become very much larger than in case of a steam engine.

In the air hoists at Butte the formation of such loops in the indicator cards is prevented by admitting atmospheric air into the cylinder as soon as the pressure of the expanded air reaches the atmospheric pressure. At all points of cut-off that are not so late as to produce incomplete expansion, the air is thus used at best efficiency.

The loss due to incomplete expansion is one that in a hoisting engine can be minimized only by increasing the volumes of the cylinders. It cannot be entirely eliminated.

In starting a hoisting engine from a state of rest, it is of great importance that the admission valves close as late as practicable in order that the engine may start readily from any position. If these valves close at 0.9 of the stroke, there is one position of the cranks in the ordinary quarter crank engine where only one of the two cylinders can take steam, and in that position the angle between the crank center and that of the connecting rod is such that only about 0.65 of the crank radius is active. The available starting torque is thus the pressure on one piston multiplied by 0.65 of the crank arm. The active crank arm decreases rapidly with shorter cut-off.

This condition is much improved in the 4-cylinder design of hoist such as built by the Nordberg Mfg. Co. for Tamarack, Calumet & Arizona and Tuolumne mines. In that type there are in the most disadvantageous crank position three cylinders out of four available for starting and a shorter initial cut-off can be used without affecting the ease of maneuvering.

The acceleration of the hoist also requires late admission; in fact, in any type of hoist air at nearly full stroke will have to be used during several revolutions of the engine. The hoisting of men is preferably done with the engine throttled and without cut-off. The loss in efficiency due to incomplete expansion is the most serious loss in an air-operated hoist. If there was a way to eliminate it, the work performed per unit of weight of air used by the engine would be very nearly the same as required to compress the same quantity of air if the heat of compression is restored by reheating, which, as has been stated above, can be done at a very small expense.

By the use of a two-stage motor the losses from incomplete expansion can be very much reduced. At a maximum filling of the cylinders of 0.9 of the stroke the loss from incomplete expansion is about one-half of what it would be in a single-stage motor or about 25 per cent. of the energy in the air entering high-pressure cylinder if the initial air temperatures in high and low pressure cylinders are equal.

Such a two-stage motor with two high and two low pressure cylinders should preferably be so designed that the time of the eight impulses produced by the cylinders is equally divided in the revolution, so that at every one-eighth of the revolution one of the pistons passes the dead center. In a properly proportioned two-stage air motor the impulse waves in the torque diagram are exactly the same for the low-pressure as for the high-pressure cylinders, so that the torque diagram has the same appearance as that produced if all cylinders were of the same size and the air expanded in a single stage. In an engine of this type, whether single or two-stage, it is not necessary to extend the cut-off to nine-tenths of the stroke, but the engine will start and maneuver easily with the admission valves set to close at a little less than 0.7 of the stroke. The loss from incomplete expansion in a two-stage motor of such design and proportions will be only 8 per cent. at 0.7 per cent. admission. The use of a two-stage motor thus gives a way to practically eliminate the loss in efficiency due to incomplete expansion. When the load conditions are such as exist in deep shafts of ore mines, such a motor will produce economical results with compressed air that could not be approached by any other mode of transmitting power.

It has already been stated that in several of the Butte mines the operators habitually retard the hoists by "plugging" instead of by the brake. "Plugging" is a process where the hoist is reversed at the time when retardation commences. The throttle is closed and the pistons of the hoist compress the air or steam entrapped back of them. The intensity of the compression is regulated by manipulating a bypass valve through which the air or steam is allowed to escape to the atmosphere. The work performed by the pistons during this process is absolutely lost and the only advantage of using it is that it saves the brakes. Frequently when plugging an engine, very high pressures are brought upon its running gear and frames.

In designing the new cylinders for these hoists, arrangements were made whereby the retardation is effected by compressing air back into the pipe line and receiver system. This is also done when, as frequently is required, loads are lowered into the mine. The compression can be regulated exactly as the expansion, i. e., the quantity of air compressed can be varied to suit the load. The manipulation of the compressor gear differs little from the manipulation of plugging to which the operators are accustomed.

In rebuilding these hoisting engines for operation with compressed air the principal parts of the old engines had to be retained. This was somewhat of a handicap as none of these engines was strong enough to admit of such cylinder diameters as we would like to have used. The High Ore and Diamond engines had cylinders 30 in. x 72 in. and the one

at Mountain View 28 x 72 in. The new cylinders were made 34 x 72 in. in all these cases. These sizes were about as large as the frames of the Diamond and High Ore hoists could stand and in case of the hoist at Mountain View, new and stronger frames were made.

The above-mentioned hoists are all fitted with reels for flat ropes and were the first ones converted. The drum hoists at Original, West Stuart, Pennsylvania, Tramway and Leonard had cylinders 32 x 72 in. when run with steam. These were provided with cylinders 34 x 72 in. All the large hoists thus have cylinders of that size. The main hoist at West Colusa originally had steam cylinders 20 x 60 in. The new air cylinders were made 23 x 60 in.

While, as has been intimated above, a somewhat higher efficiency could have been obtained with these hoists had it been practicable to use larger cylinders, still the efficiency is very satisfactory considering the here existing conditions of extremely varying loads. There has been no complete test made to determine what the exact efficiency is and it would hardly be possible to make such tests, which, in order to give exact results, would have to be made with the system as a whole. A test run with stored air on the least economical of the large hoists showed that 1.62 kw. was consumed per indicated horse power. By comparing the indicator cards of the more economical hoists with cards taken during this test we find that these hoists would consume from 1.5 to 1.4 kw. per indicated horse power.

A detailed description of the mechanism used in the Anaconda air hoist may be of interest.

The cylinders and valve gear on these hoists must perform the following functions:

In starting the hoist the throttle is opened wide and air is admitted during nine-tenths of the stroke and exhausted during the entire return stroke, producing an indicator card as shown by *a*, Fig. 28.

The hoist is now accelerated and after having made from one to three revolutions, the governor takes control, cutting off the air supply at different points of the stroke as determined by the rise of the governor. Indicator cards as per *b* are then produced at this stage of the operation.

When about six-tenths of the full speed is attained the point of closure of the exhaust valves is advanced to such a point as to cause the air contained in the clearance spaces to be compressed to the full initial pressure. As the speed increases the point of cut-off at the air inlet valves is also advanced by the governor and indicator cards as per *c* are produced.

When the governor has risen to such a height as to produce the last card in the series *c*, the air is expanded to atmospheric pressure and, theoretically the engine works at best efficiency.

In order to maintain this efficiency when the governor rises still higher

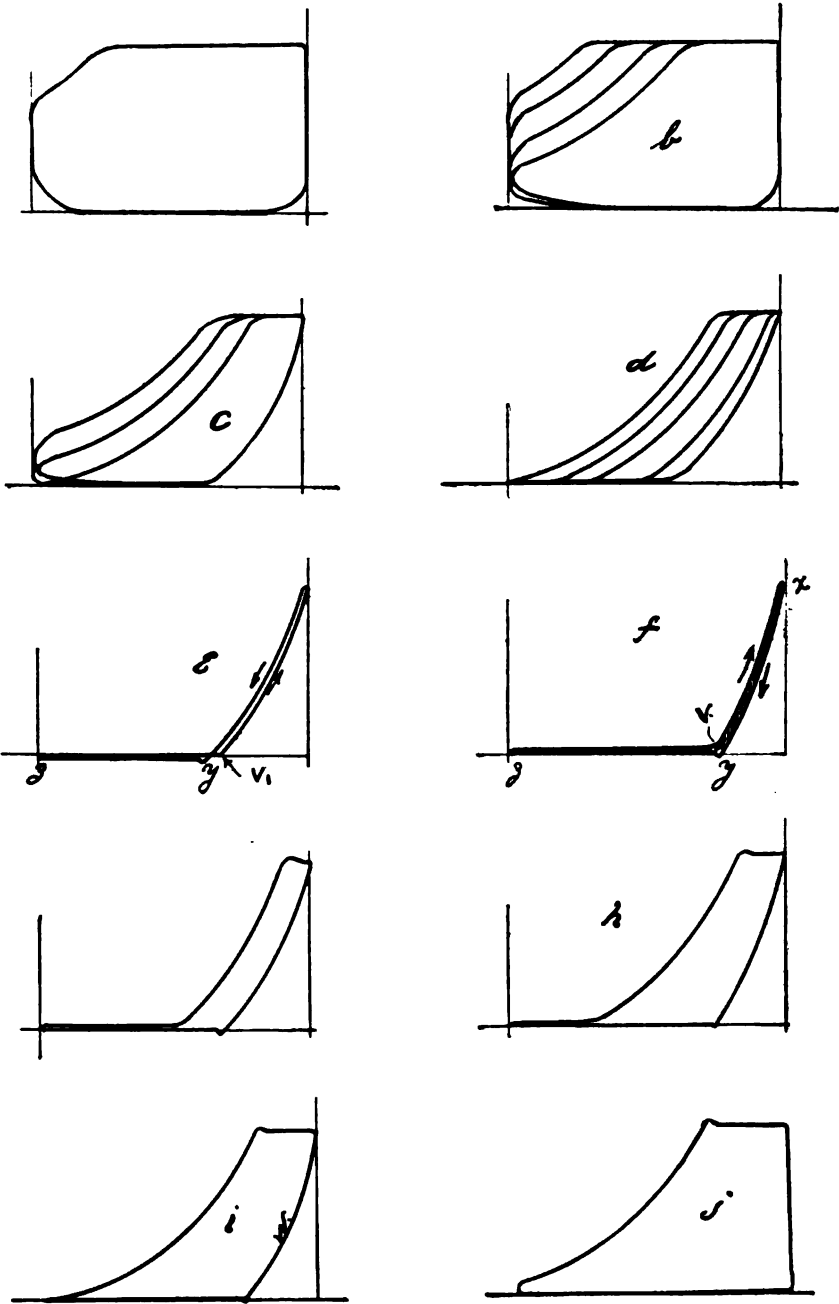


FIG. 28.—AIR HOIST CARDS.

as the load decreases, and in order to eliminate loops in the indicator cards under this condition, atmospheric air is admitted to the cylinder at all points of cut-off shorter than the last one in series *c*. This stage in the operation is shown in the diagram group *d*.

*e* shows the last diagram of the group. The air is here cut off practically on the dead center of the engine, expanded to atmospheric pressure, which pressure is maintained in the cylinder from the point of the indicator card at which the expansion line touches the atmospheric line up to the end of the stroke, and on the back stroke, to the point where recompression begins. This is the indicator card corresponding to a work =  $\pm 0$ .

While the above-described functions are performed by the valve gear of the engine, the hoist has attained its maximum speed and is now running

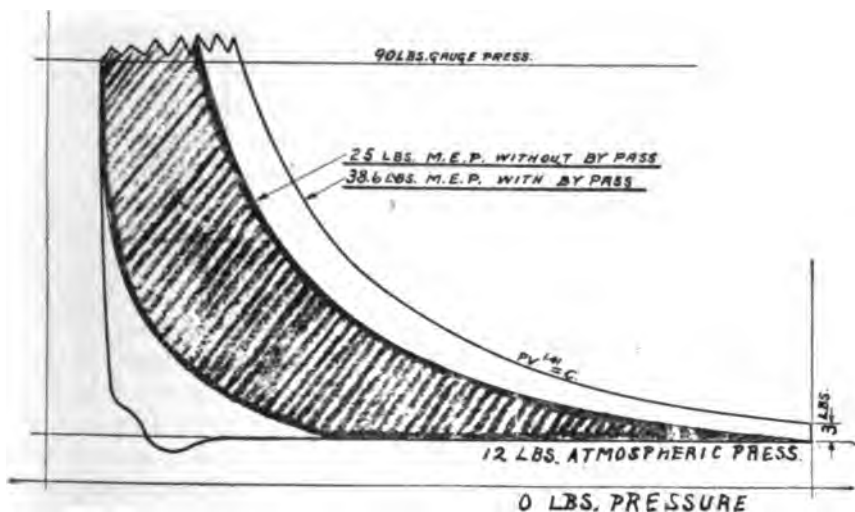


FIG. 28k.—COMPRESSION CARD FOR AIR HOIST.

under the influence of the momentum of the revolving parts and the masses attached to the ropes.

Under certain conditions of speed, friction and balance, the air could now be shut off and the hoist allowed to "run out," the masses being retarded by the friction and the increased static moment of the ascending load (if it is a reel hoist). These conditions are not frequently found so that generally the following additional functions have to be performed by the valve gear:

The hoist is to be retarded without applying the brake. The operator moves the regulating lever (which may be combined with the throttle lever) into retarding position. Thereby he causes the air-admission valve to remain closed throughout the forward and return stroke as they were when card *e* was produced. The only air present in the cylinder is that in

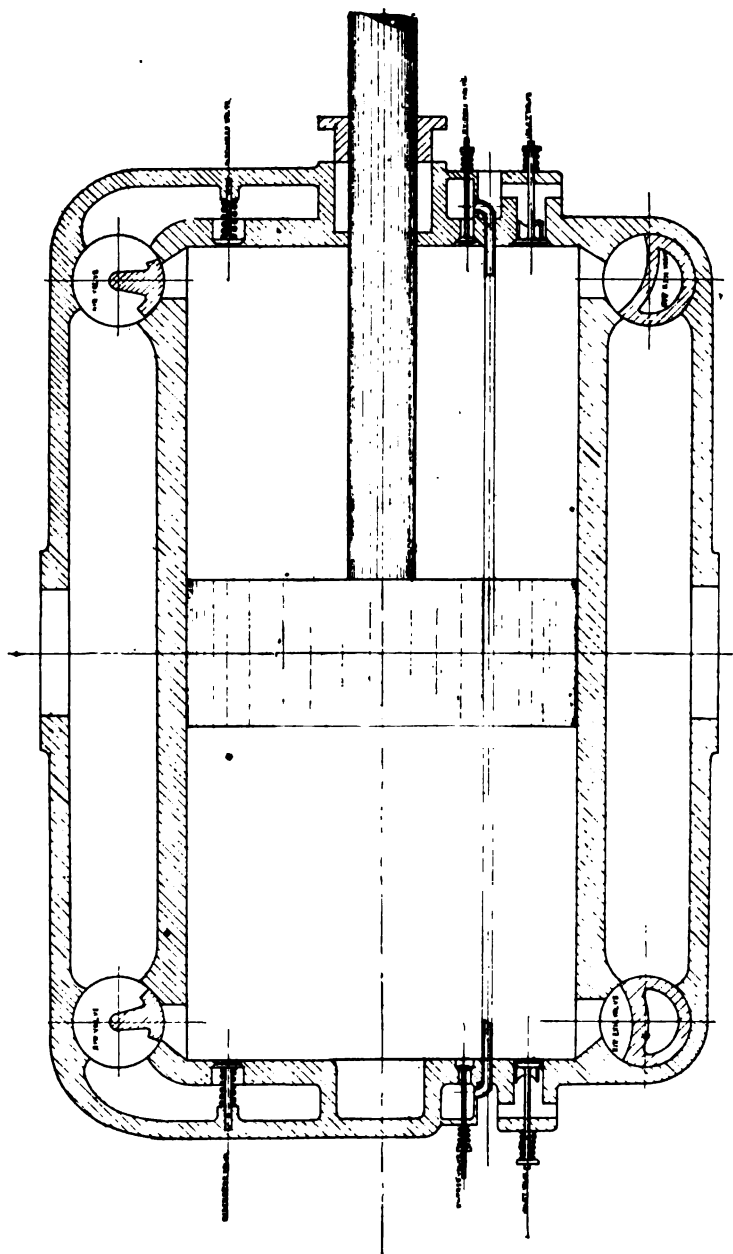


FIG. 29.—DETAIL OF AIR HOIST CYLINDER.

the clearance space which now expands as the piston progresses on its forward stroke from  $x$  to  $y$ , card  $f$ , and a further progress of the piston is accompanied with admission of atmospheric air into the cylinder from  $y$  to end of forward stroke  $z$ . The exhaust valve now opens and air is ejected during the return stroke. So far the process in producing cards  $e$  and  $f$  is identical. The regulating lever referred to above actuates the closing mechanism of the exhaust valves in such a manner as to vary the point of closure of the valves during the return or exhaust stroke of the engine. Thus, in the card  $f$ , produced when the regulating lever is barely moved from its neutral position, the point of closure of the exhaust valve has been advanced to point  $v$  in card  $f$  from point  $v_1$  in card  $e$ . The result is the shaded area of the diagram which represents a certain negative work. By further movement of the regulating lever away from its neutral position the compressor cards  $g$ ,  $h$ ,  $i$  are made in succession,  $i$  representing the compression of the full volume of the cylinder. The effect of this mechanism is to exhaust from the cylinder all air that is not to be compressed and then to compress the balance. The valve gear has such a range that any volume from the full piston displacement to zero can be compressed, and as said before  $i$  represents the indicator card produced in compressing the full contents of the cylinder. By moving the regulating lever into its extreme position, an auxiliary valve is actuated whereby communication is established between both ends of the cylinders at the time when the piston passes the dead center and while both exhaust valves are closed. This causes the compressed air filling the clearance space behind the piston to flow over to the other side, which during the previous suction stroke has been filled with air at atmospheric pressure. The result is an increase of the pressure in front of the piston of several pounds and the disappearance of the reexpansion line  $w$  (card  $i$ ) and a much higher mean effective pressure of compression which brings the hoist to a standstill.

$j$  is the indicator card produced at this the final stage of the operation. Fig. 28*k* shows the increase of mean effective pressure by applying the just described device. The shaded area in this diagram is that produced when compressing the full displacement of the air cylinders and reexpanding the air in the clearance space in the regular way. It will be seen that by this device the mean effective pressure is increased from 25 to 38.6 lb. to the square inch.

The mechanism for performing the functions above described are illustrated in Figs. 30, 31, and 32. The cylinders are fitted with Corliss valves for admission and exhaust, but in addition to these (the motor valves) there are air inlet and discharge valves of self-acting poppet type which come into action when the machine compresses air back into the air system.

Fig. 29 is a diagrammatic section of these cylinders and shows the interrelation of the different parts of said cylinders. The usual bypass valves

for establishing communication between the two ends of the cylinder are also provided on these cylinders and are indicated in the diagram. As has already been mentioned, special use is made of these valves to intensify the compression in stopping the hoist. Corliss releasing valve gear is used on all the engine valves on the admission as well as on the exhaust valves. From the description of the functions to be performed by this valve gear it follows that the valve gear must be able to close the admission as well as the exhaust valves at any point of the stroke and that the action must be the same whether the engine runs over or under. These conditions are fulfilled by the long range valve gear designed by the writer, the essential parts of which are illustrated in Fig. 33. This gear admits of any adjustment of lap and lead without in any way affecting the range of release.

In order to render the working of the valve gear as clear as possible three diagrammatic views are drawn, showing separately the devices used for the different functions.

Fig. 30 shows the mechanism for operating the throttle and for regulating the expansion of air. In this *A* is the throttle hand lever which connects to the rocker *B* by means of a slotted head *C*.

The governor *D* is also connected to the rocker *B* in a similar manner through bell crank *E* and slotted head *F*.

The rocker *B* connects by rod *H* to the admission releasing gear, the connections being such that the point of release is advanced when the parts move in the direction of the arrow. This movement is made in opposition to the weight *G* on bell crank *B*, which weight returns the parts of the releasing gear into non-releasing position when the governor drops or throttle hand lever is in "closed" position.

The throttle *I* is positively operated from hand lever *A* by means of the rod *J*. *K* indicates the eccentric operating the wrist plate *L*, and *M* the eccentric operating the releasing cams.

By the described arrangement adjustments can be made so the throttle cannot be opened wide without applying the cut-off.

Fig. 31 is a diagram of those parts of the mechanism that determine the direction of motion of the hoist. *A* is the reverse lever. (In practice this is combined with the throttle lever which has a side motion operating the reversing gear, while the forward-and-back motion performs the functions of operating the throttle and cut-off.) This lever connects through the rods and levers *B*, *B*<sub>1</sub>, *B*<sub>2</sub>, *B*<sub>3</sub>, *B*<sub>4</sub>, to the floating lever *C* of the power reversing cylinder *D*, which through lever *E* operates the four-gear reversing device. This receives its motion from crank shaft *G* by means of parallel rods *H*, *H*<sub>1</sub>. *F*<sub>3</sub> is the first motion shaft, from which the rotation is transmitted to the second motion shaft *F* by the intermediate gears *F*<sub>2</sub>, *F*<sub>1</sub>. The parts are shown in the position of running "under." The gears *F*<sub>1</sub> and *F*<sub>2</sub> are suspended on lever *E* by the link *J* and on the stationary shaft



bearings of  $F$  and  $F_2$  in such a manner that when lever  $E$  is lifted from position of running under to that of running over, the rolling of the peripheries of the gear  $F$  over that of  $F_1$ ,  $F_1$  over that of  $F_2$ , and  $F_2$  over the periphery of the stationary gear  $F_3$ , will cause the center of eccentric, which

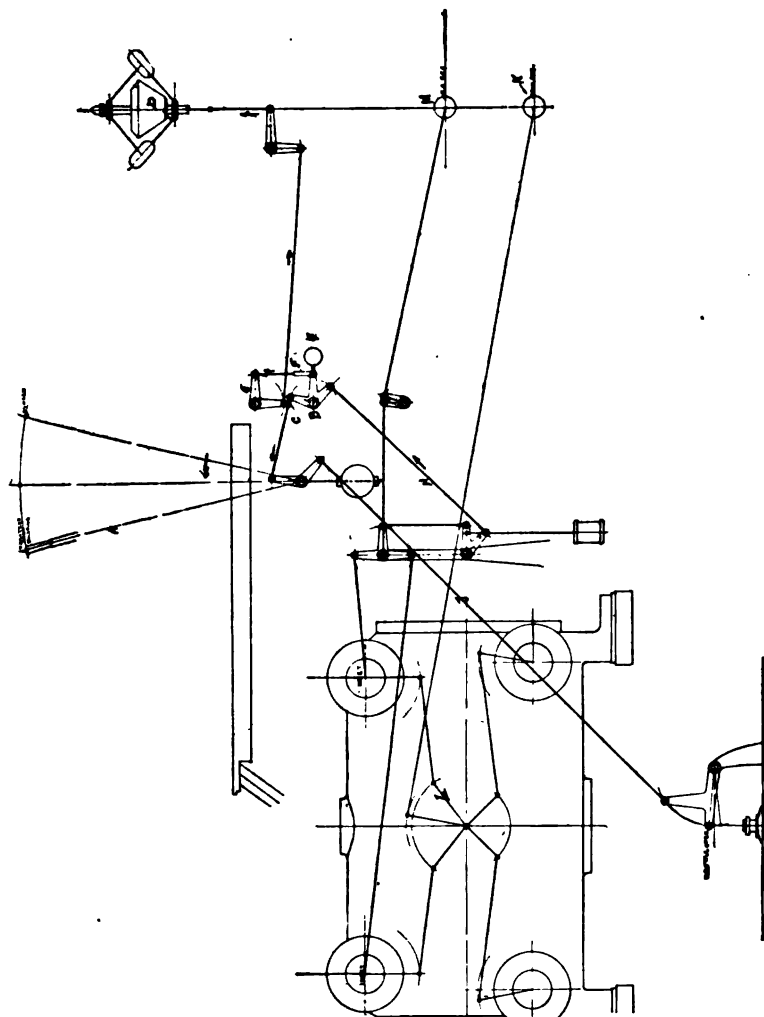


FIG. 30.—DIAGRAM OF THROTTLE, EXPANSION GEAR AND CONNECTIONS.

when running under is at  $X$ , to turn through the angle  $r$  and to assume the position  $Y$ , which is the position for running "over." Rod  $K$  connects the main eccentric to wrist plate  $L$ .

The eccentric operating the cut-off cams is mounted on the shaft  $M$ . When reversing, this eccentric has also to be turned on the shaft but through a much smaller angle. This is accomplished through the gears

$F_4$ ,  $F_5$  and the gear  $F_6$  mounted on the shaft  $M$ . This "secondary" reversing gear is operated from lever  $E$  through link  $N$ , the lever arm  $O$  being so proportioned as to turn the cut-off eccentric through the angle  $S$ , while the main eccentric describes the angle  $r$ . The cut-off reversing device actually used on the Butte hoists differs in details from the one described, being of a very compact design but the working principle is as described.

The mechanism used for converting the hoist from a motor to a compressor and for automatically compressing the air contained in the clearance spaces when engine is running at full speed and relieving the compression when running slow, is shown by the diagram Fig. 32.  $A$  is the regulating hand lever,  $B$  the cylinder fitted with Corliss admission valves,  $C$ ,  $C_1$  and Corliss releasing gear as described above.  $D$ ,  $D_1$  are Corliss exhaust valves, also fitted with Corliss releasing gear.  $E$  and  $F$  are the pendulum and parallelogram movements for the cut-off cams of the admission and exhaust valves respectively which receive their motion from the secondary reversible lay shaft in a manner as described above through the connections  $G$ ,  $G_1$ ,  $G_2$  and  $G_3$ .  $H$ ,  $H_1$  are spring-loaded air-suction valves and  $I$ ,  $I$  similar air discharge valves discharging back into the air system.  $J$ ,  $J_1$  are the bypass valves.

As has been already described, the engine is converted into a compressor by keeping the engine admission valves  $C$ ,  $C_1$  closed with reversing gear in such a position that the exhaust valves will function as they should when engine runs as a motor. Changing from motor to compressor action, therefore, is done without reversing the engine. On the forward stroke, when the exhaust valve is closed air cannot enter the cylinder through the admission valve  $C$  as it would if the valve were permitted to open and the machines acted as a motor. The result is that the suction valve  $H$  opens and air is drawn in from the atmosphere. At the end of forward stroke the exhaust valve opens and through it the air is pushed out of the cylinder up to the point at which this exhaust valve closes. The air remaining in the cylinder is then compressed and leaves cylinder through discharge valves  $I$ ,  $I$ . The point at which the exhaust valve closes can be varied so that any volume from that of the whole cylinder contents to zero may be entrapped and compressed.

For this purpose the exhaust valves are fitted with a releasing gear identical to that used on the admission valves.

The regulating lever  $A$  is shown on the diagram in its neutral position, i. e., when the machine is operated as a motor. This regulating lever is connected to the separate mechanism. By the rod  $K$  it connects to the four-way rocking valve  $L$ , which is under air pressure and the exhaust of which communicates with the atmosphere. By rod  $N$  and slotted head  $M$  it connects to the three-armed rocker  $O$ , which by rod  $P$  and bell crank  $Q$

operates the exhaust releasing gear. By the rod  $R$  bell crank  $R_1$  and rod  $R_2$  the regulating lever is connected to the lever  $S$ .  $T$  and  $T_1$  are small cylinders with pistons. These pistons are forced by springs upward in the case of  $T$  and downward in case of  $T_1$ . The opposite sides of these pistons are connected by pipes to ports in the valve  $L$  whereby they can be exposed to the pressure in the air system and moved in opposition to the springs or to the atmosphere, when the springs will move them against the heads.

In the neutral position of the regulating lever the valve  $L$  is held in such a position as to communicate the cylinder  $T$  with the atmosphere. The spring in the cylinder thus holds the piston in its highest position, allowing the pin  $E_3$  to move freely downward in the slotted head on end of piston  $T$ . In the position shown of the pin  $E_3$  and weighted rocker  $E_2$ , which actuates the admission releasing gear through rod  $E_1$  the admission valves admit air to the cylinders during nine-tenths of the stroke. The rocker  $E_2$  is the same as  $B$  in Fig. 30 and is actuated by the governor so that pin  $E_3$  may be in any position in the slot of the head on end of piston  $T$ , depending on position of governor or throttle lever. The different parts of the releasing gear on exhaust valves, rocker  $O$ , rod  $P$ , bell crank  $Q$  and pendulum  $F$  are in position to keep exhaust valves open during the entire return stroke. The rods and connections  $R$ ,  $R_1$ ,  $R_2$  hold lever  $S$  in such a position that the toe on same ( $S_1$ ) lifts the slotted block  $U_1$  on end of rod  $U$  out of reach of the tooth  $V_1$  on rocker  $V$ .

The cylinder and piston  $T_1$  is subject to the air pressure and the piston consequently in its highest position. The extended piston rod forces the rocker  $V$  against the opposition of the spring connected therewith and keeps roller  $V_2$  off the cam  $W$ , thus rendering the rocker  $V$  inactive.  $W$  is a revolving cam on the first motion valve gear shaft. This cam has two projections,  $W_1$ ,  $W_2$ , which, when piston  $T_1$  is down, roller  $V_2$  held by the spring  $V_3$  against the cam  $W$  and lever  $S$  with  $S_1$  is in such a position as to allow the slotted block  $U_1$  to engage the tooth  $V_1$ , give a motion to the bypass valves  $J$ ,  $J_1$ , keeping them open while the piston passes the dead center.

When the regulating lever is moved toward the left it moves the valve  $L$  so as to throw compressed air on top of cylinder  $T$ , the piston of which at once moves downward and shifts rocker  $E$  and the admission releasing gear in the direction shown by the arrow, thereby tripping the admission valves and preventing their opening during any part of the stroke. A further movement of the regulating lever in the direction of the arrow causes the inner end of slotted head  $M$  to engage the rocker  $O$ , moving it and parts connected with it in the direction of the arrows, bringing the exhaust releasing gear into action and advancing the point of release as the regulating lever is moved in the direction of the arrow. In the neutral

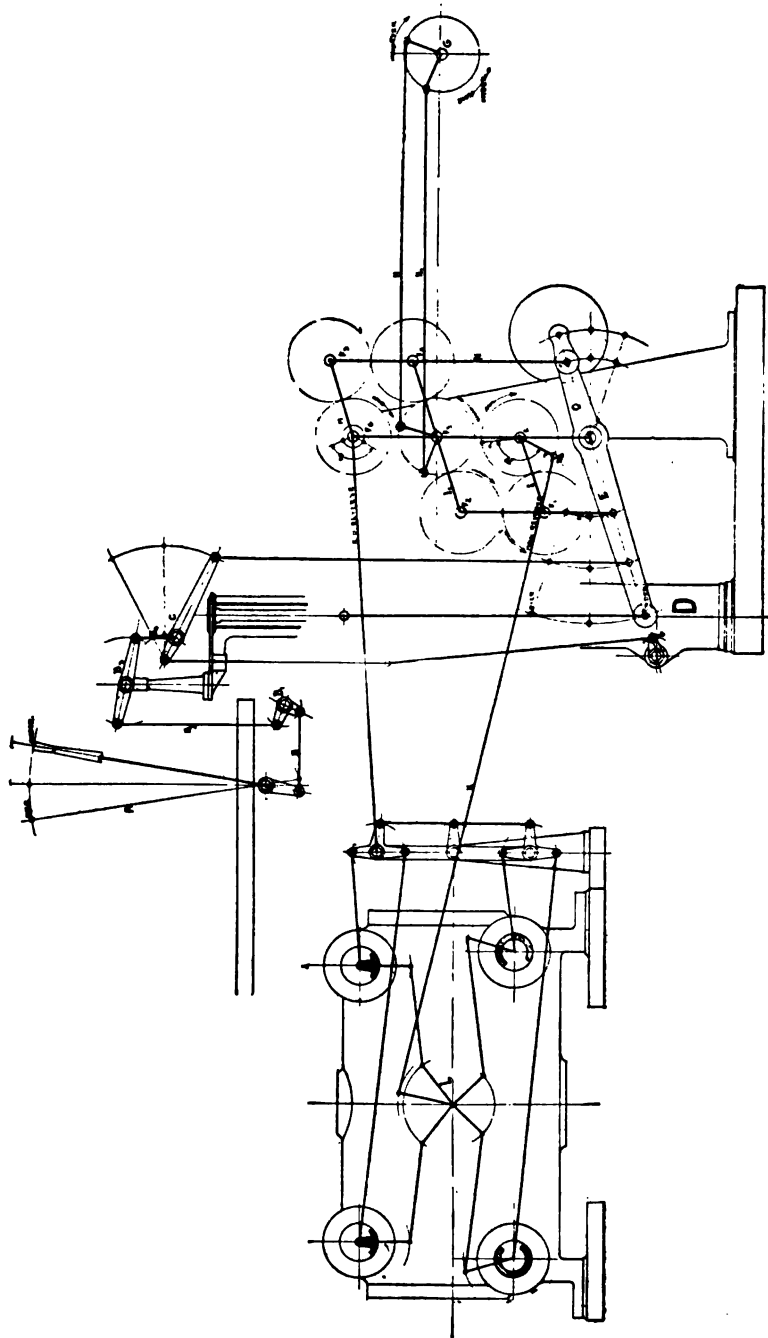


FIG. 31.—DIAGRAM OF REVERSING GEAR.

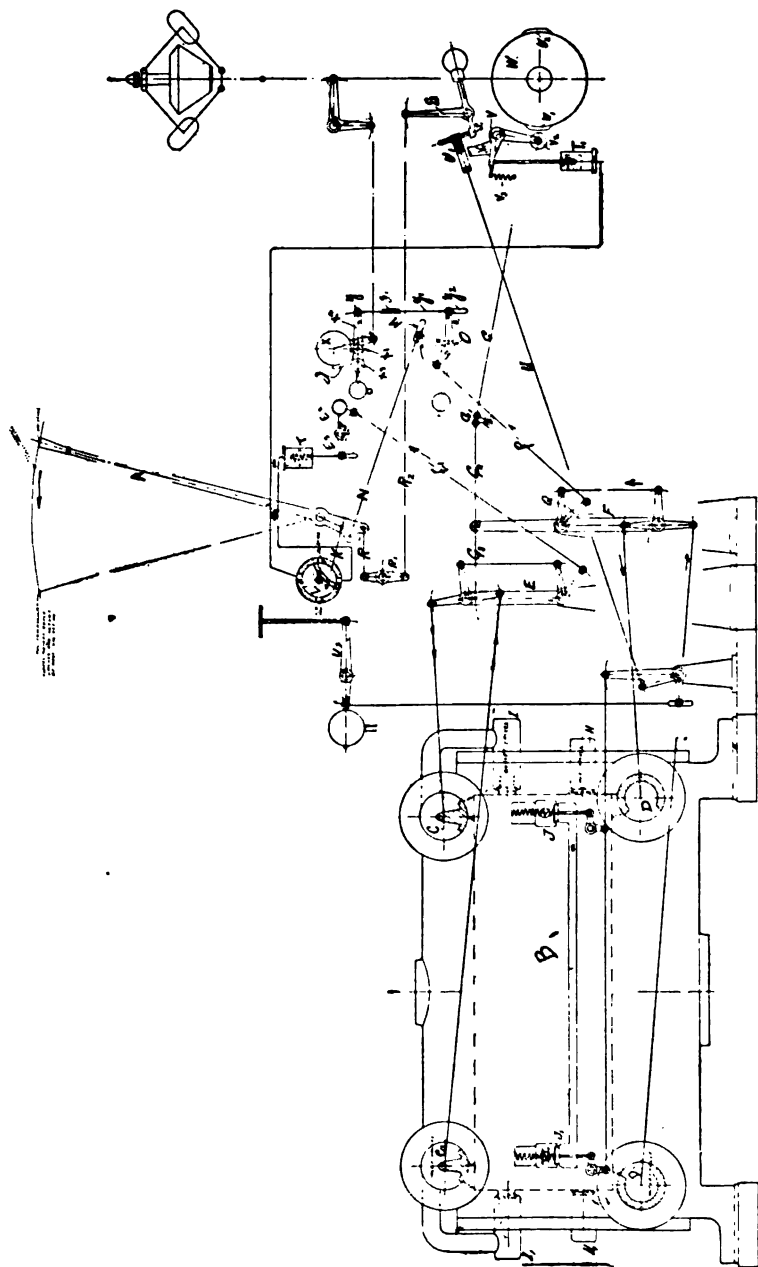


FIG. 32.—DIAGRAM OF COMPRESSION GEAR AND CONNECTIONS.

position no air is compressed while when the regulating lever is near its extreme position a volume of air equal to the piston displacement is compressed and discharged back into the air system. We have therefore here a means to regulate the retarding force with the same precision as we regulate the development of power when the machine runs as a motor.

When the regulating lever is in its extreme left position the valve  $L$  is brought into the position as shown by the dotted lines. This puts the cylinder  $T_1$  into communication with the atmosphere while it leaves  $T$  under air pressure. The piston  $T_1$  is then forced down by the spring back of it and the roller  $V_2$  on rocker  $V$  brought into contact with the revolving cam  $W$ . This causes the bypass valves  $J, J_1$  to open simultaneously on both dead centers of the engine and to close as soon as the air in the clearance space back of the pistons has passed over to the other side of said pistons and an equilibrium of pressure is established between the two sides. The initial air pressure will by this process increase from atmospheric pressure to about 3 lb. above atmosphere.

When this air is compressed a considerably higher average pressure is obtained than that resulting from compressing the full piston displacement of free air, particularly as the work of expansion, which is positive, disappears. Fig. 28*k* shows the indicator card of this intensified compression as compared with the regular full power compression card.

With the intensified compression the heaviest downgoing loads can be quickly retarded and stopped and the device as described for this purpose is an important improvement in the operating mechanism of an air hoist.

The bypass valves can be operated by a foot lever in the regular manner for landing the skips and maneuvering. These valves are at such times not actuated by the cam  $W$ .

For the purpose of recompressing air to fill the clearance spaces with air of initial pressure when the engine is up to full speed, the following device is used in connection with the exhaust releasing gear: The governor actuates a cam  $X$  engaging a roller  $X_1$  mounted on a lever  $X_2$  hung on a fixed pivot  $X_3$ . The pin  $y$  on end of this lever connects with rod  $y_1$  and slotted head  $y_2$  to arm  $O_1$  on rocker  $O$ . When now the hoist is up to speed and governor commences to rise, the projection  $z$  on cam  $x$  is brought in contact with roller  $X_1$  and as the governor lifts will move the lever  $X_2$ , rod  $y_1$  with slotted head  $y_2$  downward, thereby moving rocker  $O$  and the parts of exhaust valve releasing gear connected therewith in the direction of the arrows, thereby advancing the point of closure of the exhaust valves an amount proportional to the radial dimensions of the projection  $z$ . This dimension is such that the advanced closure of the exhaust valves entraps just enough air in the cylinders so that when it is compressed the final pressure is 90 lb. per sq. in. By means of the right and left hand screw adjustment  $z_1$  the point of release can be accurately set by the aid

of the indicator. As long as the governor stands a small distance over its collar and the engine is up to speed the compression as described takes place. This not only entirely eliminates the clearance loss but produces smooth running of the engine.

When the speed is dropped and the governor returns to its collar the cam *X* and projection *z* of same are automatically moved out of reach of roller *X*<sub>1</sub>. The rocker *O* and parts connected to same are thereby caused

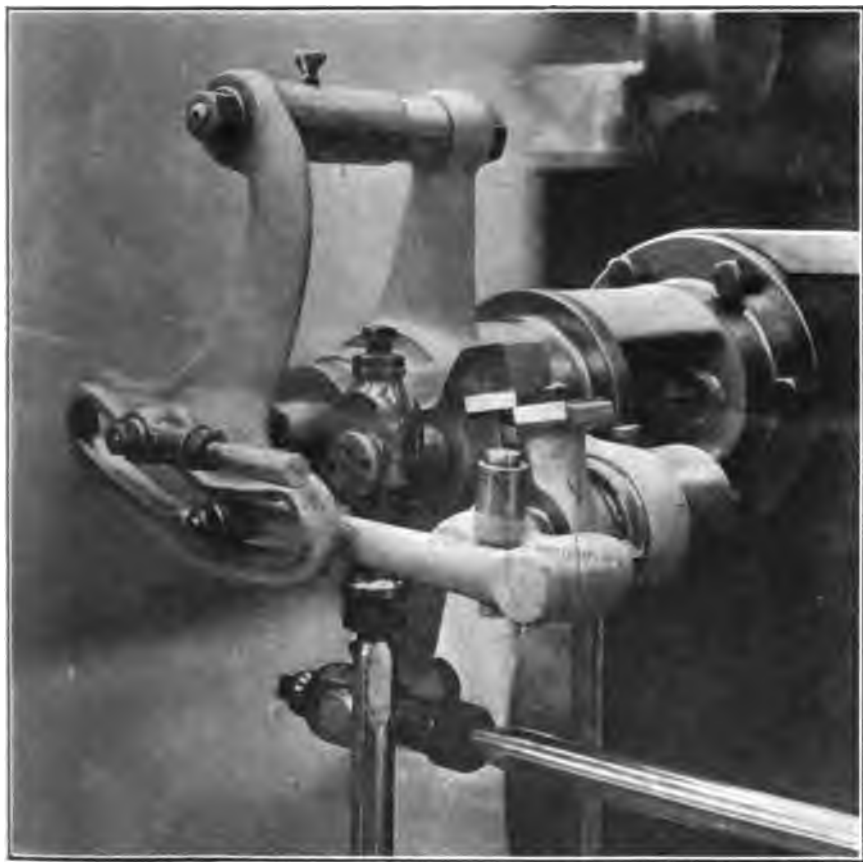


FIG. 33.—FULL STROKE VALVE GEAR.

to return into the position of non-release of the exhaust valve gear. The compression which, if present under low speed, would seriously interfere with the maneuvering of the hoist, now disappears.

The continuous indicator diagrams Figs. 38 to 42 were all taken from different air operated hoists in the Butte camp, fitted with the above described valve gear, and show how well it performs the different functions.

SCALE 1 INCH = 240 LBS PER 10 IN.

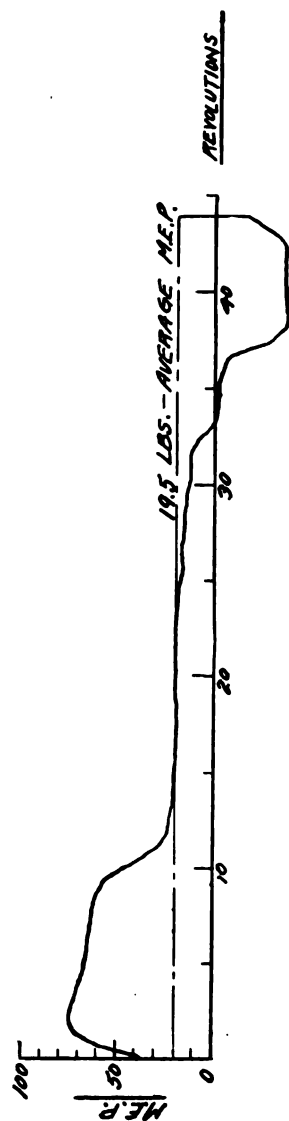


FIG. 34.—HOISTING CARD TAKEN AT THE LEONARD MINE FROM THE RIGHT-HAND HEAD END OF A 34-34 BY 72 AIR HOIST, 12-FT. DRUM, RUNNING BALANCED. SKIP OF ORE HOISTED 1,800 FT. IN 45 SECONDS.



SCALE 1 INCH = 240 LBS PER SQ. IN.

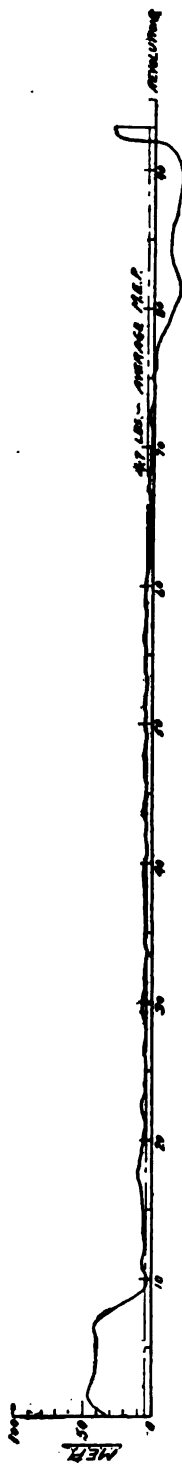
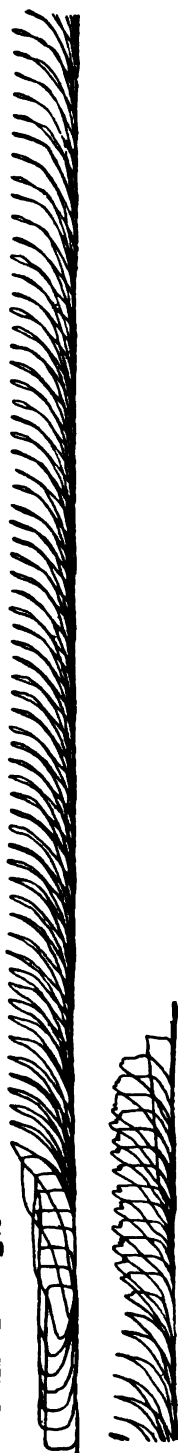


FIG. 35.—HOISTING CARD TAKEN AT THE MODOC MINE FROM THE LEFT-HAND HEAD END OF A 28-28 BY 48 AIR HOIST, 6-FT. DRUM, RUNNING BALANCED. TWO DECKS OF CAGES AND TWO CARS OF WASTE HOISTED 2,000 FT. IN 55 SECONDS.

SCALE 1 INCH = 240 LBS. PER 30 IN.

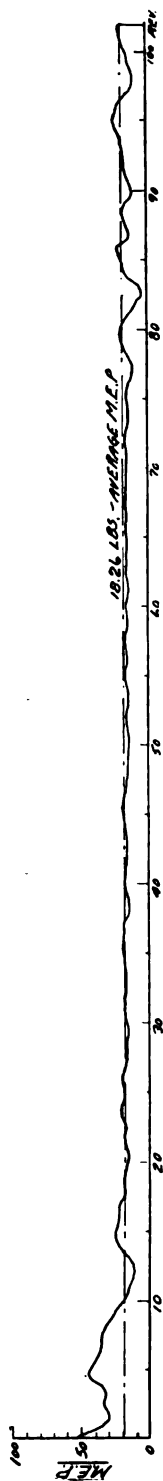
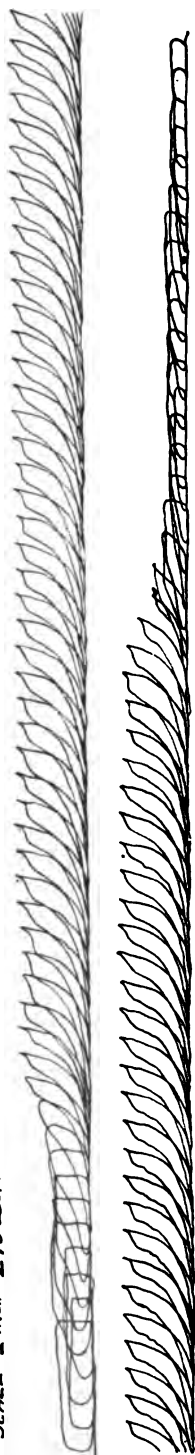


FIG. 36.—HOISTING CARD TAKEN AT THE TRAMWAY MINE FROM THE LEFT-HAND CRANK END OF A 28-28 BY 48 AUXILIARY AIR HOIST, 6-FT. DRUM, AIR PRESSURE 92 LB. PER SQUARE INCH, RUNNING UNBALANCED. THREE CAGES AND THREE EMPTY CARS HOISTED 2,000 FT. IN 60 SECONDS.

Fig. 34 is taken from the main hoist at Leonard mine when hoisting a balanced load of ore from the 1,800 ft. level. The first five strokes require full filling of the cylinders. Five more strokes are performed with reduced filling but at the 11th stroke the clearance compression gear comes into action. The filling is gradually reduced to zero and at the six strokes at the end of the run air is compressed back into the system.

This hoist has cylinders 34 x 72 in. and 12 ft. drums carrying  $1\frac{1}{2}$  in. ropes.

Fig. 35 is from the new 28 x 48 in. double drum hoist at the Modoc mine. The drums here are 6 ft. diameter and carry 1 in. ropes. This card shows how efficiently the described valve gear works with very light loads. As there is no clearance loss during the greater part of the run the air consumption is very small. The card shows that for retarding the hoist air was compressed back into the system during fourteen strokes.

Figs. 36 and 37 are indicator cards from the single drum auxiliary hoist at the Tramway mine. This hoist has cylinders 28 x 48 in. and the drum is 6 ft. diameter. The work of this hoist is mostly negative as it is used for lowering waste rock into the mine to fill out empty stopes. It runs out of balance.

Card Fig. 36 is taken when the empty cages are hoisted while card Fig. 37 is taken when the cages loaded with 3 cars of waste rock were lowered into the mine. The machine is run as a compressor when this work is done.

Card Fig. 38 is from the main hoist at the High Ore mine. This hoist is fitted with reels for flat ropes. The card is taken when hoisting from a depth of 2,800 ft. in balance. Here the air is shut off after a little over two-thirds of the run is completed. The balance of the run is made with the momentum of the moving masses as a driving force which, at the end of the run, just balances the friction and static moment of the load.

The mean effective pressures of the individual cards of these continuous diagrams are plotted below the diagrams. The average values of all the mean effective pressures are also given.

The installation of this plant was commenced in the latter part of 1910, when the hoists at Mountain View, High Ore and Diamond were reconstructed and three compressors installed. The Mountain View hoist was started on air in the early spring of 1911 and the other two soon thereafter. The performance of these three hoists was regarded so successful that six more hoists were changed over and twelve new auxiliary hoists ordered all of which were designed on the same principles as the original three hoists.

The compressor plant was also extended. It now contains six compressors. Two more compressors are being built. About three-fourths of the air from this plant is used for operating the hoists and the balance is used to help out the rock drill system.

SCALE 1 INCH = 320 LBS PER SQ. IN.

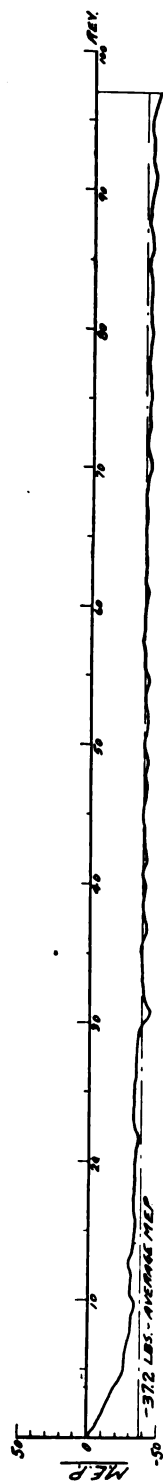
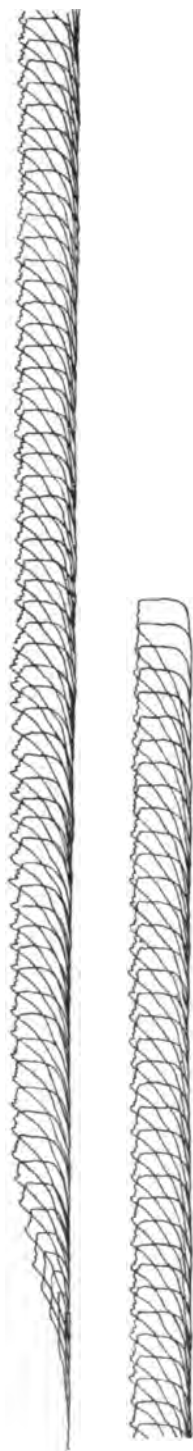
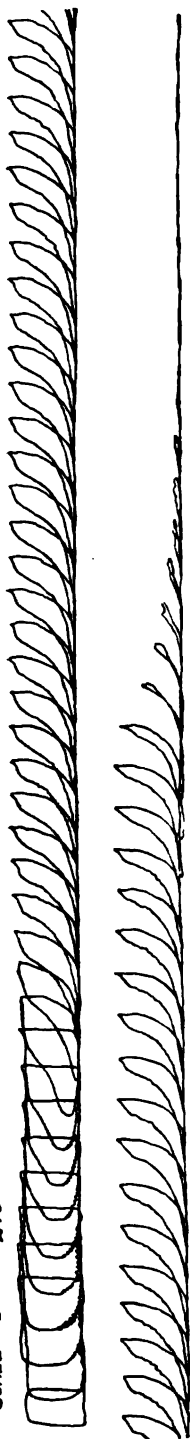


FIG. 37.—LOWERING CARD TAKEN AT THE TRAMWAY MINE FROM THE RIGHT-HAND HEAD END OF A 28-28 BY 48 AUXILIARY AIR HOIST, 6-FT. DRUM.  
THREE DECKS OF CAGES AND THREE CARS OF WASTE LOWERED 2,000 FT. IN 70 SECONDS.

SCALE 1 INCH = 240 LBS. PER SQ. IN.



End of Run

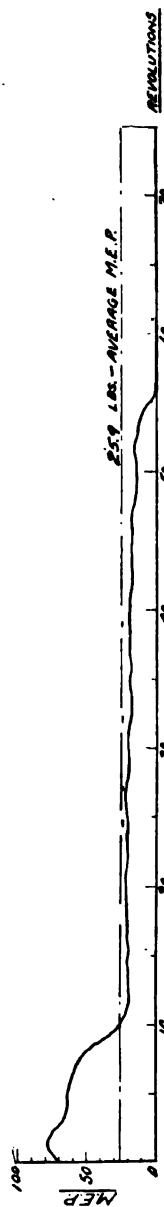


FIG. 38.—HOISTING CARD TAKEN AT THE HIGH ORE MINE FROM THE LEFT-HAND CRANK END OF A 34-34 BY 72 AIR HOIST RUNNING BALANCED. SKIP OF ORE HOISTED 2,800 FT. IN 60 SECONDS.

It was originally contemplated to regulate the hoisting so that the active periods of the different mines would not occur at the same time. So far it has not been found practical to do this to any great extent, the result being that at times the storage system is overtaxed.

The advantages of this adopted system over any in which electric motors are directly applied to the hoists are the following:

(1) The existing hoisting engines could be retained and needed comparatively few changes.

(2) They could be operated by steam in case of a serious accident to the power system.

(3) Enough energy is always available in the storage plant to operate the hoists for a short time in case of a short failure of the electric power due to thunder storms, etc.

(4) The capacity of the hoists can be increased, by increasing the hoisting speeds of the loads or the hoisting depth can be increased without changing the motor on the hoist. The compressor capacity only needs to be increased.

(5) A considerable part of the energy liberated in retarding the hoists at the end of a run or when loads are lowered into the mine is returned to the power system and is held in storage without loss for an extended period.

(6) The system can be started with its stored energy without subjecting the electric apparatus to excessive peak loads as is the case when a fly-wheel of an Ilgner transformer is started.

(7) By this system of compressing, storing and using the air in the hoist cylinders, peak loads on the electric apparatus are absolutely avoided. No matter how the load on the hoist motors may fluctuate, the power to operate the electric motors in the compressor plant is absolutely constant.

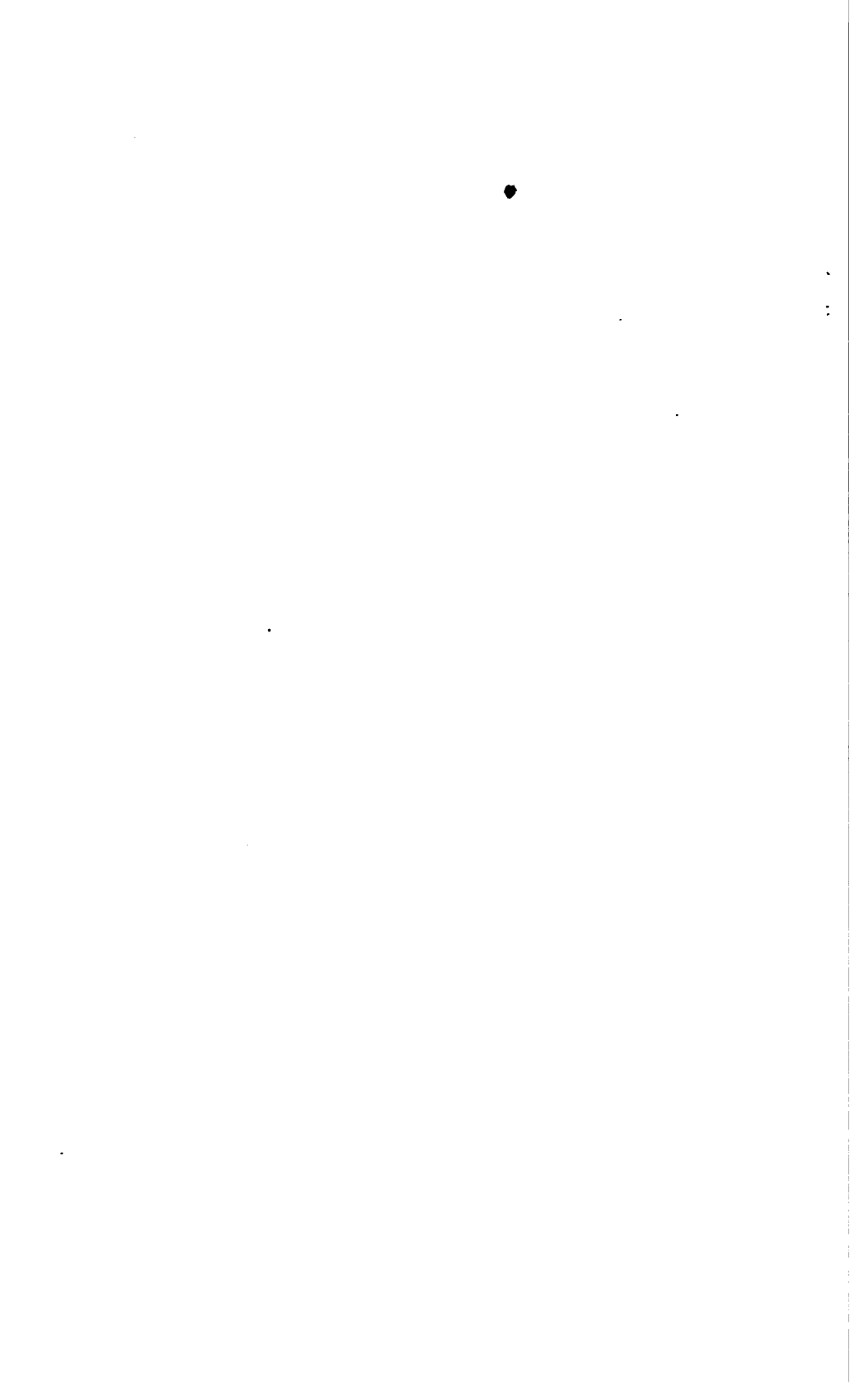
(8) Compared with electric hoists the air system has the following electrical advantage: With the air hoist, the electric prime movers are synchronous motors which can be operated with a leading power factor and therefore raise the power factor of the entire electrical system, while with an electric hoist, the prime mover is an induction motor which would have a very low power factor due to the intermittent loads it would have to carry to meet the Butte conditions of hoisting and hence would decrease the power factor of the entire electric system.

As compressed air is used for operating the rock drills it seems consistent and natural, when electric power is used for compressing this air, to enlarge the compressing plant so that the hoists also are operated by air. In most cases of ore mining it will be found that the increase in compressor capacity necessary for hoisting with air is not very large. If proper air storage is provided, the result will be a simpler, cheaper, safer and more economical plant than if the hoists were directly driven by electric motors

and motor generators with heavy and fast rotating flywheels were used. The high peak loads resulting from starting these flywheels and from the irregularity of hoisting will be avoided and the electric load will be perfectly constant.

The plant has been a success and the writer believes that it has fulfilled the expectations of the owners. The mechanism used for performing the different functions in both the compressors and the hoists were new, and applied in practice for the first time in the plant. Since the machinery was started there have been no interruptions in its work and very little trouble.

In a new plant operated with compressed air many improvements could be made that were not possible in the Butte plant. Some of these improvements would be of very radical nature and would result in obtaining very high efficiencies without in any way impairing the reliability of the machinery or ease of operation, which, after all, is the most important thing in a mine hoist.





DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Butte meeting, Aug. 18 to 21, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1913, when Vol. XLVI. of the Transactions will go to press. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## **The Southern Cross Mine, Georgetown, Mont.**

BY PAUL BILLINGSLEY, BUTTE, MONT.

(Butte Meeting, August, 1913.)

### *Introduction.*

THE Georgetown mining district is located in Deerlodge county, Mont., about 20 miles west of Anaconda. It lies along the divide between the headwaters of Warm Springs creek, draining eastward, and Flint creek, flowing west and north through the Philipsburg valley.

The actual divide is formed by Cable mountain, a narrow ridge running north and south, terminating to the south in low hills overlooking Georgetown lake, and to the north in a high, rugged plateau that falls off to the west to the wide valley of Flint creek. On the eastern, or Warm Springs, slope of Cable mountain is the Cable mine, with the Hidden Lake mine a few miles north. On the western slope is the Southern Cross group, with smaller mines, the Twilight, Cincinnati, Red Lion, and Big Bill, at intervals to the northward. The Georgetown mines lie in the hills south of Cable mountain; the Philipsburg mines, of which the Granite Mountain, Bimetallic, Hope, and Trout are the chief, form a separate group to the north, overlooking Flint Creek valley and Philipsburg. (See Fig. 1.)

The region ranges in elevation from 5,000 to 9,000 ft. It is, with the exception of the lower valleys, well timbered with small fir and pine, although Cable mountain and the higher summits to the northward rise slightly above timber line. The main valleys have the smooth contours of glaciation, and their mouths are frequently choked with morainal deposits.

### *General Geology.*

In a very general way the valley of Flint creek coincides in this region with the boundary between the pre-Cambrian slates of western Montana and the folded Palæozoic rocks of the Rocky Mountain system. The great limestone formations of the Carboniferous and Devonian, lying at flat dips, extend from Anaconda well toward the head of Warm Springs creek, but on the divide the Cambrian appears, closely folded and intruded

by irregular masses of granite. Cable mountain itself is an anticline of the basal Cambrian quartzite and underlying shales, flanked by steeply dipping limestones. The strike of the beds coincides with the north-south direction of the ridge. On the south the fold is terminated by the small granite mass that extends from Cable to Georgetown, and on the north abuts against the edge of the larger Philipsburg batholith. The distance between these granite areas is about 7 miles; the width of the anticline about 2 miles. In this limited area the Cable, Red Lion, and Southern Cross groups are located.

The ore deposits of the district may be conveniently classified into four types: 1. Fissure veins in granite; 2. Contact metamorphic deposits; 3. Fissure veins in limestone; and 4. Replacement bodies in limestone.

The Granite-Bimetallic mines are, of course, the chief representative of the first class, and the Cable mine is an equally well-known instance of the second. These mines have been described in detail by W. H. Emmons<sup>1</sup>. The third and fourth types overlap somewhat, and both may often be found in a single mine, but at their extremes they are represented by the Gold Coin, a quartz-filled fissure with no replacement of the walls, and by the Southern Cross, a characteristic replacement deposit in limestone.

### *History.*

The Southern Cross claim was located in 1866, but this first location was allowed to lapse, and the ground was relocated by Salton Cameron several years later. Cameron developed the Southern Cross vein, and shipped some ore to East Helena. Stamp milling was first attempted in 1884, but the results were unsatisfactory. Under the management of a Butte company production increased, and by 1893, 30,000 tons, with a gross value of \$750,000, had been shipped.

In 1904 the mine was leased by Lucian Eaves, who discovered a new ore body to the west of the old Southern Cross vein. This yielded more than \$300,000 gross. In 1906 the property again changed hands. The New Southern Cross Mining Co. installed a wet mill and prosecuted vigorous development work. This resulted in the discovery of new ore bodies between those formerly exploited, and greatly increased the probable life of the mine. In 1910 the Anaconda Copper Mining Co. purchased the property, and in the year following built a railroad from Browns spur, 5 miles from Anaconda, to the mine. The ore, high in iron and desirable as a flux, is smelted direct at the Washoe Smelter, so that the two great difficulties of the past, the long wagon haul and the refractory milling character of the ore, need not be contended with in the future.

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<sup>1</sup> *Bulletin No. 315, U. S. Geological Survey (1907).*

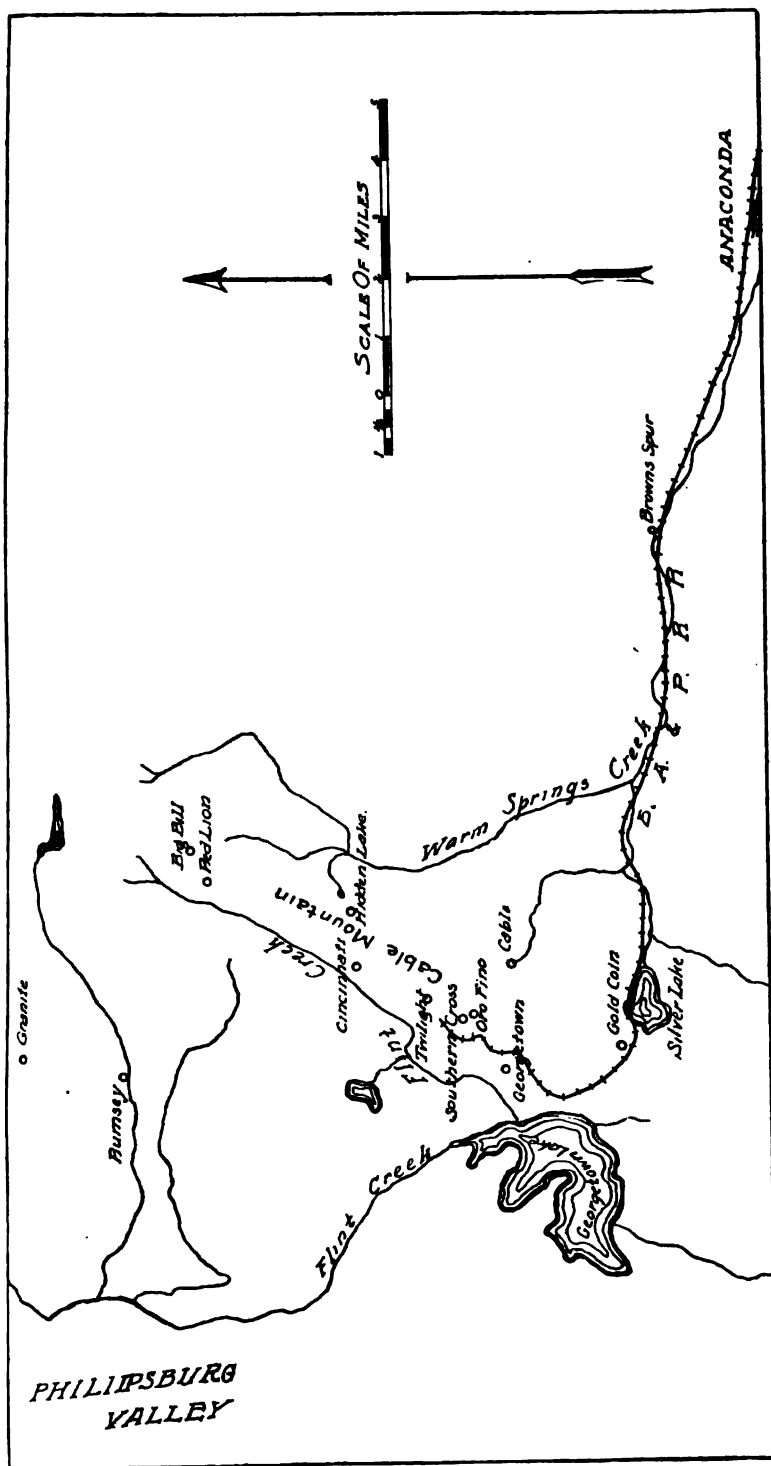


FIG. 1.—INDEX MAP OF THE GEORGETOWN DISTRICT, DEER LODGE COUNTY, MONT.

*Geology.*

The ore occurs as replacement bodies in limestone. The sedimentary succession in the district consist of the following members in ascending order:

|                        |                                             |                                                                          |
|------------------------|---------------------------------------------|--------------------------------------------------------------------------|
| Pre-Cambrian . . . . . | 1. Spokane shale.—Red and green shale.      |                                                                          |
|                        | 2. Flathead Quartzite.—White quartzite.     |                                                                          |
|                        | 3. Silver Hill Formation.—Calcareous shale. |                                                                          |
| Cambrian . . . . .     | 4. Hasmark Formation . . . . .              | { Lower magnesian limestone.<br>{ Shale.<br>{ Upper magnesian limestone. |
|                        | 5. Red Lion Formation . . . . .             | { Shale.<br>{ Laminated limestone.                                       |

At the mine these strike slightly east of north, and dip from 50° to 60° to the west. The productive members of the series are the two magnesian limestones of the Hasmark formation. The Oro Fino ore body is near the base of the lower; the ore bodies thus far developed in the Southern Cross are in the upper, between the characteristic crinkly Red Lion limestone and the calcareous shale member of the Hasmark. Fig. 2 shows the general relation of the ore and the strata.

The limestones in the mine are not, in general, strongly metamorphosed. Certain favorable beds are locally changed to finely crystalline white marble, but the contact minerals, tremolite, garnet, etc., are conspicuously absent. On the surface the granite of the Cable batholith appears about 2,000 ft. south of the mine, cutting across the sediments at right angles. Underground, however, a small, badly decomposed dike in the southern part of the Southern Cross workings and a similar intrusion in the Oro Fino are the only indications of igneous activity.

Faulting likewise occupies a subordinate place in the geology of the mine. Certain of the ore bodies which cut across the bedding may occupy pre-mineral fractures; smaller fissures, with a strike of N. 80 W. and steep eastward dip, sometimes prominent as walls of the ore bodies, may indicate very slight post-mineral displacement; and a fault with the same strike and dip traverses the northeastern portion of the workings. The pre-mineral fractures, however, can rarely be followed for a score of feet beyond the vein filling, and the later faults have a displacement too slight to affect the ore bodies otherwise than by offsetting the walls into irregular steps. The limestone itself shows no extensive crushing or deformation.

The country rock at the Southern Cross, therefore, consists of massively bedded magnesian limestones, locally recrystallized but with little contact metamorphism, and comparatively undisturbed by faulting.



*Character of Ore Bodies.*

The ore consists of irregular bodies of soft gold-bearing iron oxides, replacing the limestone. The common minerals are limonite, hematite, siderite, and magnetite, with lesser amounts of quartz and calcite. The two first mentioned, with partly replaced earthy limestone, form the greater portion of the ore. Carbonates of copper are occasionally found, coating the iron minerals and concentrated in the porous portions of the limonite. A residual brown clay is common around the borders of the deposits.

Sulphide ore has not been encountered in the workings to the present depth of the mine—400 ft.—but residual bunches are occasionally found in the oxidized ore bodies. These bunches occur as pyrite cores, surrounded by massive hematite or limonite, and traversed by cracks and fissures of the partly altered sulphide. The entire amount of this material is slight, but the separate occurrences are so similar as to be strongly suggestive of the primary ore underlying the oxidized zone.

The uniform character of the limestone and the absence of strongly defined bedding planes have combined to give the deposits extreme irregularity of outline. With these factors reduced to a minimum, the extent of the replacement has been determined by such remote and obscure causes as local intensity of the mineralizing solutions, pre-mineral cleavage planes, and varying solubility of portions of the limestone. With the destruction of such evidence that extensive replacement involves, the determining causes of the form of the several ore bodies are obscure.

*Structural Relations.*

The main bodies lie in four groups, each marked by certain common features. (See Fig. 3.) The earliest ore mined came from the Southern Cross vein. This is a fissure cutting across the bedding, with a strike of N. 40° W. and a dip of 60° to the northeast. In the favorable magnesian limestones this fissure has been the nucleus of considerable replacement, but where it cuts across the shale member of the Hasmark formation it is a small, tight crack difficult to trace. The ore body of the Southern Cross vein has an average length in the limestone of 200 ft.

Probably associated with this in origin is the Pleiades vein, an irregular ore body replacing the limestone immediately above the Hasmark shale. It roughly parallels the bedding. This vein cannot be traced above the Southern Cross fissure, and is strongest immediately below it, passing into a narrow stringer along a bedding plane a short distance away. At its best it forms an ore body about 50 ft. in length.

The third series of shoots, collectively called the Glory vein, is likewise

parallel to the bedding. It outcrops 200 ft. west of the Southern Cross vein, and, dipping to the west, diverges from it more and more with depth. This ore is, like the Pleiades vein, near a shale-lime contact, and follows, in a general way, the base of the lower Red Lion shale. The chief ore shoot averages 200 ft. in length, with other smaller bodies along the general zone.

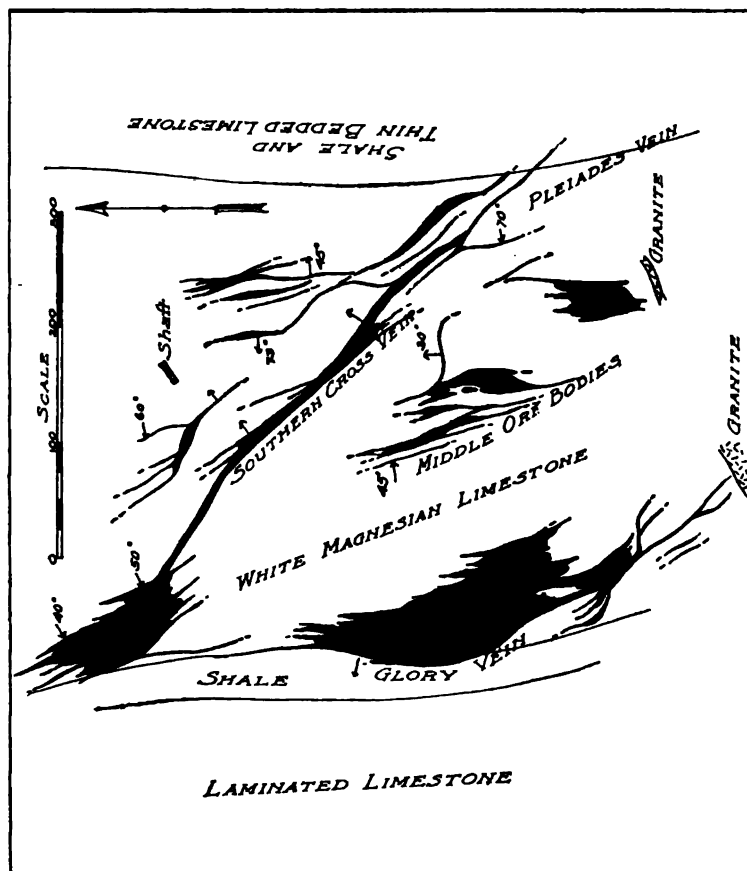


FIG. 3.—DISTRIBUTION OF ORE BODIES IN THE SOUTHERN CROSS MINE.

A certain broad system is thus discernible in the above groups of ore bodies—a cross fissure dipping east, with associated replacement in favorable strata; and replacement shoots running from this along lime-shale contacts on both sides of the massive limestone member. The fourth and most recently discovered group is far less simple in relationship. It lies within the massive magnesian limestone itself, between the

Glory vein on the west and the Southern Cross-Pleiades ore bodies on the east. The ore bodies of this group show much greater replacement of the lime than any of the preceding, with less regularity of outline. The boundaries coincide locally with bedding planes, and locally with the small post-mineral fractures above mentioned, but most frequently cut across the bedding at irregular angles. These shoots lie in large, roughly lenticular masses pitching northward at flat angles. Their dimensions, as thus far developed, exceed those of the earlier ore bodies.

### *Origin of the Ores.*

Any theory of the origin of these ore bodies confronts certain difficulties. The fact of limestone replacement is clear, but the source of the active solutions is less obvious. The coincidence in the entire district between the magnesian lime of the Hasmark, the edge of the granitic batholiths, and the iron ore bodies is striking. Many of the latter, however, are a thousand or more feet away from any exposure of igneous rock, so that if, as seems probable, the granite is the source of the mineralizing solutions, the replacement bodies represent a relatively remote phase of their action. At the actual contact there is a great development of calcite, wollastonite, garnet, and magnetite, and several large bodies of the latter extend well into the limestone. It is therefore possible that the lime-silicate zone, the magnetite bodies, and the replacement bodies of the Southern Cross represent progressive stages of contact metamorphism, proceeding from the contact itself out into the sedimentary rocks.

The general relation of the Southern Cross ore bodies points to the Southern Cross fissure as the most probable channel for the introduction of the mineralized waters. From this fissure the solutions worked out in such favoring localities as lime-shale contacts to form the Pleiades and Glory veins, while smaller fractures and bedding planes admitted them into the intervening limestone bed which now contains the middle ore bodies.

There can be but little doubt that the ore was originally deposited as sulphide, and that the present occurrence of the oxides is due to the action of surface waters. It is true that hematite is not rare as a mineral of contact metamorphism, and may have been present with the pyrite of these deposits, but the cores of sulphide found at such widely separated points as the Oro Fino, Southern Cross, and Red Lion mines can hardly be explained otherwise than as the remnants of the original ore. The oxides also frequently form pseudomorphs after pyrite. There is in addition much evidence that alteration from the surface is subsequent to the formation of the ore bodies. Natural caves in the limestone are of frequent occurrence, often in close proximity to the ore, and in no instance are the



iron oxides found filling such cavities. On the other hand, bodies of ore often form the hanging wall of the caves. It is probable, therefore, that these openings are largely due to the action of surface waters rendered acidic by the oxidation of the overlying pyritic ore bodies.

A few instances in which such caves have been filled with the débris of surface waters are so unlike the typical deposits of the mine as to be instructive in this connection. The best examples are found in the Oro Fino Red Lion mines, but they are not lacking in the Southern Cross itself. These caves are filled with a partly consolidated mass of heterogeneous boulders, cemented in places with iron oxide, but mostly imbedded in sand and gravel. The boulders comprise quartzite, granite, and shale, as well as limestone, and the source of supply is obviously the surface soil and wash. Many such deposits have been developed in the district, but none have contained commercial ore.

### *Summary.*

The ore bodies thus far exploited in the Southern Cross mine, therefore, consist of the oxidized portions of pyritic replacement deposits in limestone. The ore was derived from the nearby granitic intrusions, forming the remotest, and probably the latest, phase of the contact metamorphism. Well defined cross-fissures have apparently admitted the solutions to the limestone strata most susceptible to their action, and on both borders of these favorable beds irregular deposits of gold-bearing pyrite replaced portions of the lime. Bedding planes and small cleavage cracks determined the extent of additional replacement within the limestone itself. With the geological evolution of the region the upper portions of the ore bodies became oxidized, and the resulting acidic surface waters formed caves throughout the limestone. Such of these caves as further erosion opened to the surface were filled with detritus.

The oxidation, and circulation of surface waters, has resulted in the leaching of the gold from portions of the deposits, and its concentration and reprecipitation in certain channels in the oxides. From these channels came the high-grade ore that periodically repaid the prospecting of the early operators, but under the conditions initiated by the construction of the railroad this search for "ore within ore" is no longer necessary, and in the genesis of the deposits, rather than in the nature of their enrichment, are found the clues to the successful development of the mine.



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## Ore-Dressing Improvements.

BY ROBERT H. RICHARDS, BOSTON, MASS.

(Butte Meeting, August, 1913.)

### *Introduction.*

WALTER RENTON INGALLS recently gave a very interesting talk before the student mining society of the Massachusetts Institute of Technology. In it he showed the present status of mining as he sees it. In the talk he explained that, while discoveries of great mining districts are still possible, they are being made less and less often; that the great mining companies, although there are large numbers of mines offered for sale, are finding it less and less possible to find new mines that are up to the standard of richness that they wish for purchase.

The natural conclusion is that better, cheaper, and more efficient methods of mining, concentrating, and smelting are needed if the lower-grade mines are to be worked at a profit. This is true also if the high-grade mines are to yield their greatest profit.

This paper deals only with the concentrating or ore-dressing problem, and gives some thoughts which point towards greater profit.

In a paper on The Development of Hindered-Settling Apparatus the writer showed that there were two main lines of work that would lead to greater saving, lower tailing assay, and, therefore, greater profit.

The first is the recrushing of middling or tailing products for the saving of the contained values. This is well understood and largely carried out in existing mills.

The second is the saving of fine free mineral at the first opportunity. This is a matter less well understood in the mills, and to dwell upon this the present paper is written.

The writer is himself convinced and hopes to convince the reader that, for obtaining the above result, not only is better classification needed, but also more classification; that is, there should be more spigots or pockets to the classifier. His attention was recently called to a small mill which had a three-pocket cone classifier fed with from 2 to 0 mm. stuff, supplying feed to four Wilfley tables. The first spigot had about all the

sand and a great amount of slime, the second and third spigots and the overflow were about all slime. As a result, all four Wilfley tables had wide bands of slime on them and all their tailing products were charged full of fine free mineral. In fact, the cone classifier was not classifying the ore at all, and the mill process was greatly harmed from the lack of classification. It is a proved fact that when the feed to a Wilfley table carries slime, then the Wilfley tailing will carry fine free mineral. When this ore was tested in the laboratory it easily yielded 12 spigots, all of which when fed to Wilfley tables gave no slime bands on the table, and the fine free mineral was absent from the tailing of all the coarser Wilfley tables and present only in small quantity in a few of the finer.

### *Better Classification and More Classification.*

All classifiers which classify by a rising current of water have a feature which we call the sorting column, in which the sand is trying to settle, and is allowed to settle or is prevented from settling, according to the size and weight of the grains, by the velocity of the rising current of water, a stronger current lifting larger and heavier grains, a weaker current lifting smaller and lighter grains. This sorting column, whether square or cylindrical in shape, will have adverse downward currents of water carrying slime down into the spigot, thus defeating the whole object of classification unless some special provision is made to stop it.

To obtain better classification, and prevent the adverse down currents two methods have been employed:

1. Causing a vortex or horizontal rotation in the sorting column.
2. Using a pulsating rising current.

Both of these methods give better classification by destroying the hurtful downward current, avoiding the carrying of slime into the spigot, and preventing fine free mineral from going into the tailing of all the coarser Wilfley tables.

To obtain more classification we simply lengthen the classifier, using more pockets. As the benefit of this may not be apparent to the concentrator man, figures are here given to prove the point:

### *Three-Spigot Classifier.*

| Spigot.       | Quartz.                   | $\frac{3}{4}$ of the quartz             |
|---------------|---------------------------|-----------------------------------------|
|               | Diameter,<br>Millimeters. | is galena.<br>Diameter,<br>Millimeters. |
| 1.....        | 6.3 to 2.15               | 6.3 to 0.614                            |
| 2.....        | 2.15 to 0.73              | 0.614 to 0.208                          |
| 3.....        | 0.73 to 0.25              | 0.208 to 0.0715                         |
| Overflow..... | 0.25 to 0.00              | 0.0715 to 0.0000                        |

*Twelve-Spigot Classifier.*

| Spigot.        | Quartz.                   | $\frac{1}{15}$ of the quartz<br>is galena. |
|----------------|---------------------------|--------------------------------------------|
|                | Diameter,<br>Millimeters. | Diameter,<br>Millimeters.                  |
| 1 .....        | 6.30 to 4.79              | 6.30 to 1.37                               |
| 2 .....        | 4.79 to 3.66              | 1.37 to 1.05                               |
| 3 .....        | 3.66 to 2.80              | 1.05 to 0.80                               |
| 4 .....        | 2.80 to 2.14              | 0.80 to 0.61                               |
| 5 .....        | 2.14 to 1.63              | 0.61 to 0.47                               |
| 6 .....        | 1.63 to 1.26              | 0.47 to 0.36                               |
| 7 .....        | 1.26 to 0.96              | 0.36 to 0.27                               |
| 8 .....        | 0.96 to 0.73              | 0.27 to 0.21                               |
| 9 .....        | 0.73 to 0.56              | 0.21 to 0.16                               |
| 10 .....       | 0.56 to 0.43              | 0.16 to 0.12                               |
| 11 .....       | 0.43 to 0.33              | 0.12 to 0.094                              |
| 12 .....       | 0.33 to 0.25              | 0.094 to 0.071                             |
| Overflow ..... | 0.25 to 0.00              | 0.071 to 0.000                             |

We will take two instances: 1, the classifier which has only three pockets (see table) and is classifying stuff from 0.25 in. (6.3 mm.) to 0; 2, the classifier with 12 pockets, treating the same product. We will suppose that the classification is being done upon quartz (sp. gr. 2.64) and galena (sp. gr. 7.5) ore, and we will consider it to be a free-settling classifier, which will demonstrate the point better than if hindered settling was used. It will be borne in mind that with free settling the classified products after the first spigot and before the final overflow will contain grains where the quartz is approximately 3.5 times the galena in diameter.

If we consider any pair of products except the first, which in both instances has the added increment in it (see paper on The Development of Hindered-Settling Apparatus), and the overflow, both of which require special treatment, different from that of all the intermediate spigots, we believe it will be clear that a Wilfley table treating the second spigot of the three-spigot classifier, which has to separate 0.614 to 0.208 mm. galena from 2.15 to 0.73 mm. quartz, will not have so easy a task as the Wilfley table which treats the second spigot of the 12-spigot classifier and has to separate 1.34 to 1.001 mm. galena from 4.70 to 3.51 mm. quartz. The same opinion will hold if the third spigot of the three-spigot classifier is compared with the twelfth spigot of the 12-spigot classifier, and is true of all the intermediate spigots of the 12-spigot classifier. The comparison would be much stronger if quartz, 2.65 sp. gr., and pyrite, 5 sp. gr., were used, and still more so if quartz, 2.65 sp. gr., and blende, 4 sp. gr., were used.

To put the case still more strongly the writer adds the following facts:

The late George Woodbury, of California, found that the Wilfley table could not compete with the vanner in treating unclassified feed of the gold mills of the mother lode of California which were treating 100 tons a day, more or less. He did not locate the cause of this difference between the machines, or, if he did, he did not make his views public. At the Massachusetts Institute of Technology we have located the cause. The chief loss in the tailing of the Wilfley or vanner, when treating unclassified feed, is the presence of fine free mineral. The maximum size of the grains of fine free mineral in the tailing of the Wilfley table is larger than that of the vanner. This amply explains Woodbury's observation. We have many measurements on these sizes, but want better check results before we publish them.

Next, let us see what a long classifier with many spigots will do, which a short classifier cannot do. We shall find, as we follow on down from the coarser spigots toward the finer, that Wilfley tables will yield tailing products free from fine free mineral and, therefore, at the minimum assay that can be obtained without further re-grinding. After a time, however, we shall arrive at a spigot where the heavy mineral in the spigot is the same size as the normal size of Wilfley fine free mineral. Then the Wilfley table breaks down, can no longer yield clean tailing, and the vanner should take its place, because the fine free mineral in the vanner tailing is smaller than that in the Wilfley table. If we follow still further down the spigots we shall find a spigot or the final overflow where the size of the heavy mineral is the same as the size of the fine free mineral in the vanner tailing. Then the vanner breaks down, can no longer yield clean tailing, and we go to the new great Anaconda round table, which takes all the rest down to the size of the heavy mineral that floats away in a slow-moving stream of water. With this the methods of water-gravity separation of fine material, that are now in sight, close.

The critic will say: "But you are diluting your slime beyond reasonable limits by using so many pockets." The writer answers that that depends upon whether the classifier is evenly fed. If it is not, the water may be unreasonably large in quantity, but if devices can be installed that give even, constant feed, as for instance, those in the Utah porphyry mills, then there need be no fear of excess water. The following argument will show this: Suppose we have to classify 400 tons in 24 hr., and we wish to classify into 15 spigots. It takes 3.5 tons of water to 1 ton of sand for feeding the classifier; again 3.5 tons of water rising in a sorting column to allow 1 ton of sand to go down to the spigot, whether coarse or fine; again 3.5 tons of water to 1 ton of sand to discharge it through the spigot. Next, suppose we need 350 tons per 24 hr. from the spigots and 50 from the overflow. What difference does it make whether we settle the 350 tons of sand in one spigot against (multiplying by 3.5) 1,225 tons of rising

water, or settle the 350 tons of sand divided out between 15 sorting columns, requiring 1,225 tons of rising water also divided out between the 15 sorting columns. The 15-spigot classifier, then, if it is steadily and evenly fed, requires no more water and delivers overflow no more dilute than a one-spigot classifier.

The writer believes he has clearly proved that both better classification and more classification are needed.

Let us see what difficulties, if any, have to be overcome in order to put good classifiers into a mill. 1. No one has yet succeeded in designing a good classifier that does not require some attention. The concentrator man who swears by fool-proof machinery and declares that nothing shall go into a mill that is not absolutely fool-proof can never get good classification or make the highest saving. 2. There is a certain lack of breadth about concentrator men who, naturally enough, perhaps, like to have their own machines, and refuse to allow the machines of outsiders to succeed in their mills. One instance of this may be mentioned. A classifier which had a screen in it was tested in a mill. In some way unknown to the designer the screen had holes develop in it as large as a crowbar would make. The manager asked the concentrator man to have samples taken and assays made to see what results the classifier would give. Of course the result was as bad as could be and the classifier was condemned and thrown on the junk pile. If the holes came by accident, the classifier was not in fit condition to test. This paragraph really belongs to the discussion of professional ethics, which has been so much under discussion lately. For example, has a concentrator man a right to turn down good machinery by unfair tests and deprive the stockholders of his company, whose money pays his salary, of the extra dividend that might be developed?

If, then, it be admitted that fool-proof machinery of certain classes is bad machinery and that more perfect performance can only be obtained where the machine requires greater care, how can this care be secured? The answer is, get a higher-priced man to inspect and see that the machines are run properly and are always in good order.

Good classification can save large sums of money, \$25,000, \$50,000, \$100,000 or more a year. If to run such classifiers we require a \$1,500 man and three of him for the three shifts, it would pay well to spend \$4,500 a year to make any of the above figures of saving; \$4,500 is only 18 per cent. of \$25,000 and 9 per cent. of \$50,000. What successful business man hesitates to spend 25 or even 50 per cent. of the net income in advertising in order to make the business? It is common, every-day custom. Then why should we not spend 18 or 9 per cent. of the increased net income in order to bring ore dressing to the highest pitch of profit?

The conclusion, then, is that we need better classification, more classification, and higher-priced, broader-minded men to see that the greatest benefit is derived from the improved machinery.





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## Use of Electricity in Mining in the Butte District.

BY JOHN GILLIE, BUTTE, MONT.

(Butte Meeting, August, 1913.)

PRIOR to the year 1902 electricity was used in the Butte district only for lighting, for the tramming of ores on the surface, and for the electrolytic refining of copper. In that year the Canyon Ferry hydro-electric plant on the Missouri river, with a transmission line to Butte and Anaconda, was completed, and enabled the mining operators to purchase electric current in large quantities at reasonable rates, and its application and use in the various mining operations and reduction works proceeded rapidly.

The principal applications of electric current in metal mining may be listed as follows:

- Compressing air for hoisting.
- Compressing air for rock drills and pneumatic tools.
- Pumping.
- Ventilating.
- Lighting.
- Tramming.
- Compressing air for blast furnaces and converters
- Running shop and miscellaneous motors.

### *Compressed Air for Hoisting.*

The Anaconda Copper Mining Co. operates 22 mine shafts and plants at Butte. Of these, 15 are large plants and hoists, through which most of its ores are hoisted.

In 1912 this company commenced using compressed air in place of steam, in operating a number of its large hoists, and at this date has 10 main hoisting engines and 10 auxiliary hoists driven by compressed air.

The compressed air is furnished from a central plant containing six compressors, each having a capacity of 7,500 cu. ft. of free air per minute compressed to 90 lb. pressure in large receivers, and conducted by suitable pipe lines to the various hoists, the air being reheated before passing to the engines. Each of these compressors is driven by a 1,200-h.p. synchronous motor, directly attached to the drive shaft, and takes electric current at 2,200 volts. Two additional compressors are being installed,

making eight in all, which will complete the compressing plant. Seven of these machines will run continuously, and they will use 8,000 e.h.p. The excess air, or blow-off, goes into the rock-drill air system.

The hoisting engines, as formerly used with steam, had cylinders 30 or 32 in. in diameter and 72 in. stroke. To adapt them to the use of compressed air, the old cylinders were replaced with new ones, 34 in. in diameter, having valve mechanism of the most approved type.

### *Compressed Air for Rock Drills.*

The air in rock-drilling operations is used at 85 lb. pressure, and for the large operations is usually furnished from three or four central plants, the smaller mines using individual machines. A total of 13,455 e.h.p. is used for this purpose, and the voltage used is from 440 to 2,200.

### *Pumping.*

In draining the mines electrically driven pumps are very generally used, and a total of 4,780 e.h.p. is necessary. The large pumps are quintuplex vertical plunger type, with a capacity of 600 gal. against a head of 1,200 ft. The smaller units are of various types. Centrifugal pumps are not used on account of the acid nature of the mine waters.

### *Ventilating.*

The mines of the Butte district are warm, due to the oxidizing of the sulphide minerals, and forced ventilation is largely resorted to. Twenty-five hundred electric horse power is used for driving ventilating fans. In addition to fans and blowers, compressed air is used after blasting to clear the mines of powder gases and foul air.

### *Tramming.*

Electric locomotives are being introduced in all tramming, both underground and surface, and this work requires 1,860 e.h.p. Direct current 500 volts is used for surface tramming; D. C. 250 volts is used for all underground tramming. There are a few storage-battery locomotives in use at Butte, but the general system is trolley, using D.C. 250 volts. The mine locomotives are 18-in. gauge, weight 3 tons, have two 10-h.p. motors, and a draw-bar pull rated at 1,200 lb. The average load hauled per trip is 12 tons, including weight of cars and ore, on the usual mine track with grade of 0.5 per cent.

### *Lighting.*

Underground, the stations, main cross-cuts and drifts are electrically lighted, as well as the surface plants and property. A total of about 1,300 h.p. is used for this purpose.

*Ore-Reducing Works.*

At Butte, Anaconda, and Great Falls, all the Butte ores are treated. In the case of zinc ores, concentrates containing about 50 per cent. of zinc are produced, and these are shipped to the natural-gas districts for smelting and recovery of the metals.

For copper ores about 80 per cent. is reduced to the extent of making converter or blister copper, containing the gold and silver, which for further refining and separation is shipped to the large electrolytic refineries on the Atlantic coast. The remaining 20 per cent. is fully treated or reduced, and merchantable wire bars and other forms of finished copper are produced, and the gold and silver is also separately obtained. This is done at an electrolytic refinery at Great Falls. In these ore-reducing plants 24,177 h.p. are used, in driving concentrators and blowing engines, and in operating cranes, shops, and the different power machinery in connection therewith.

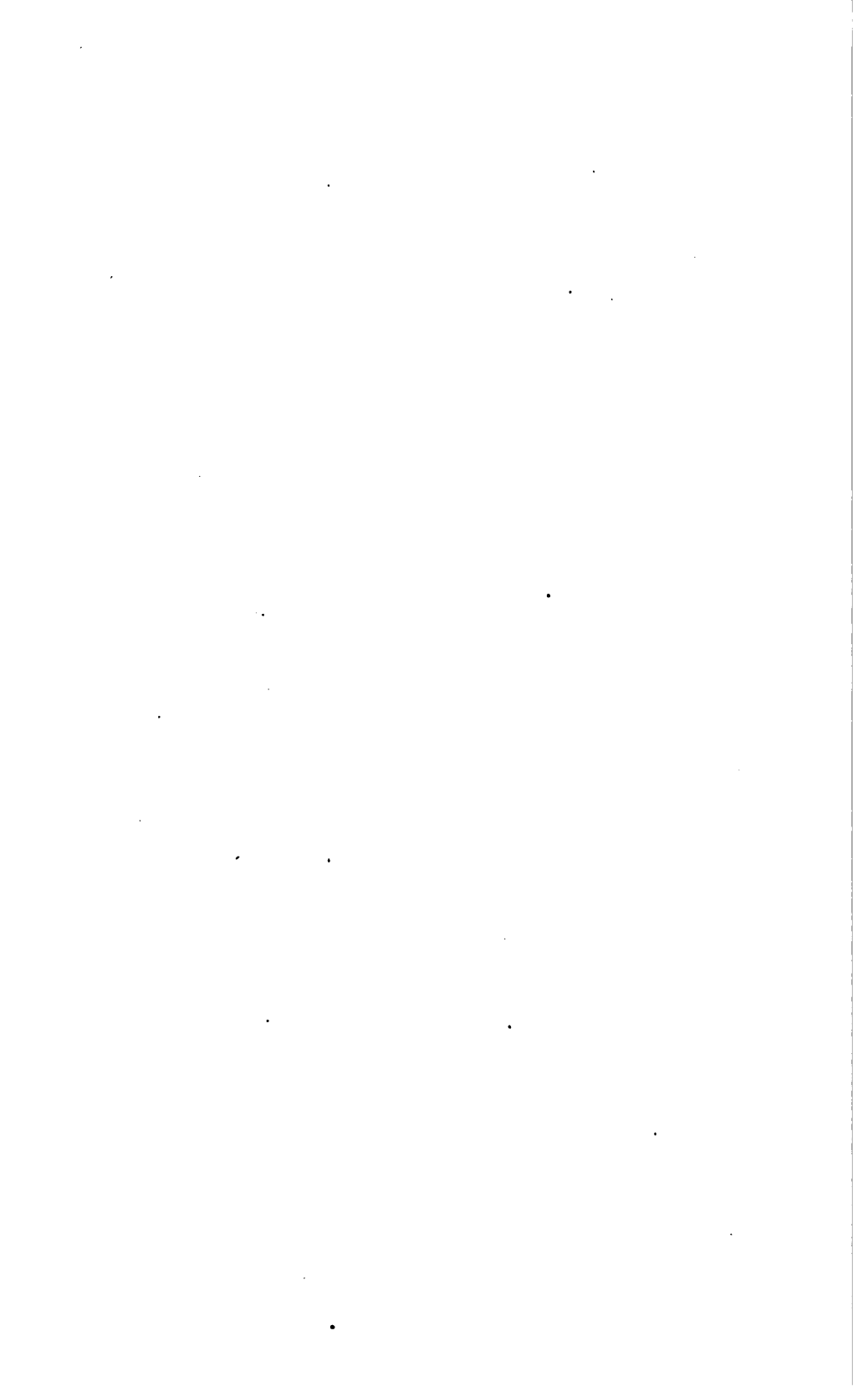
*Other Applications of Electricity.*

In connection with the use of electricity in mining, it might not be out of place to briefly mention the electrification of the Butte, Anaconda & Pacific railway, which is now nearly completed. This railroad connects the mines at Butte with the reduction works at Anaconda, and handles about 5,000,000 tons of freight yearly, consisting of ores from the mines and supplies of all kinds to both mines and smelters. In addition to the freight hauled, the passenger business between the two cities is taken care of by this road. The conditions, including grades, curvature and climate, are sufficiently severe to thoroughly prove this method of railway transportation.

The constructing engineers have adopted for this work a 2,400-volt D. C. system, with overhead trolley. Freight locomotives will consist of two units, each weighing 80 tons. Passenger locomotive will be one 80-ton unit geared higher to permit of a speed of 45 miles per hour. A part of the road has been electrically operated for several weeks, and is working very satisfactorily.

Near the famous old placer camp of Virginia City, Mont., about 90 miles southeasterly from Butte, four large placer dredges are operated by electrically driven motors, and are proving an entire success.

Not all of the applications of electric energy to mining have been given here, but enough to show that where electricity can be procured at proper prices and conditions it is a most valuable aid to both miner and metallurgist in effecting economies in their business.



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## A Note on the Occurrence and Manufacture of Refractories in Montana.

BY W. H. GUNNISS, GREAT FALLS, MONT.

(Butte Meeting, August, 1913.)

WHEN the copper smelters were built, in Montana, all of the refractory products which were used in their construction were shipped in from Eastern factories. It was apparent that if a material suitable for the manufacture of these products could be found within the State, a saving of freight could be effected and a new industry built up.

Prospecting for such materials was started and experiments were made with samples from numerous deposits. Considerable effort and funds were expended in an attempt to manufacture silica brick from Dillon quartz, a light colored sandstone that is found near Dillon, Mont., on the Oregon Shortline railroad. As a brick material the Dillon quartz was a failure, but it has proved very satisfactory as a silica cement. It is now being used in laying silica brick and for reverberatory furnace bottoms.

A bed of quartzite that is particularly suited to the manufacture of high-grade silica brick was finally discovered at Browns Spur, 6 miles west of Anaconda. The material from this deposit is now being used in the manufacture of the Anaconda silica brick, which have gained a wide reputation for heat-resisting and lasting qualities. The analysis of an average sample of this quartz is:  $\text{SiO}_2$ , 96.7;  $\text{Fe}_2\text{O}_3$ , 0.3;  $\text{Al}_2\text{O}_3$ , 2.5;  $\text{CaO}$ , 0.3 per cent. The very low percentage of fluxing ingredients makes this a most refractory material.

All of the Anaconda silica brick are hand molded. Various types of brick machines have been tried, but the hand-mold process proved the best suited to the manufacture of silica brick from this material. The silica is first put through a jaw crusher and is then dumped into wet pans, where 4 per cent. of lime paste is added, to produce a bond. Without the lime the material would not be plastic enough to mold. After a few minutes' grinding in the wet pans the material is conveyed to the molder, who forces it into the molds by hand. The brick are then dumped on pallets and placed in the drier, where they are left until dry enough to be set in the kilns. Some of the brick are re-pressed before being dried. They are burned about five days, in round down-draft kilns. It is not necessary to have as much heat in the kilns as the brick will be subjected

to when in use in the furnaces. Montana refractories are used in smelters throughout the West.

Prospecting for fire clays was also carried on. After experimenting with clays from several different deposits, it was found that a mixture of 40 per cent. of a flint fire clay (which is quarried on Lost creek, 4 miles east of Anaconda) and 60 per cent. of a plastic fire clay (which is mined near Armington, Mont.) made an excellent fire brick.

The flint clay from Lost creek is unlike the typical flint clays of Pennsylvania, though a very good fire clay. It is a light colored rock, analyzing:  $\text{SiO}_2$ , 71.6;  $\text{Fe}_2\text{O}_3$ , 1.3;  $\text{Al}_2\text{O}_3$ , 20.2;  $\text{CaO}$ , 0.4 per cent.

The plastic fire clay mined at Armington is of a very good quality. It is found in the Kootenai formation. The deposit has a thickness of from 4 to 5 ft., and occurs about 26 ft. above the Kootenai coal horizon. It is slate colored, fine grained and homogeneous, breaking with a sub-conchoidal fracture. The analysis of this clay is:  $\text{SiO}_2$ , 55.7;  $\text{Al}_2\text{O}_3$ , 30.8;  $\text{Fe}_2\text{O}_3$ , 1.1;  $\text{CaO}$ , 0.2;  $\text{MgO}$ , 0.5; alkalies, 2.1; loss on ignition, 10.2 per cent. The fire brick are manufactured at the Anaconda plant by the same process as is used in making the silica brick. At the Great Falls plant of the Anaconda Copper Mining Co., the fire brick are made by what is known as the dry press process.

Comparative tests have been made by placing fire brick from Eastern factories beside the Montana fire brick, in the furnaces. The result has been that the Montana brick stood the tests as well as any of the celebrated refractory brick manufactured in the East.

Refractory wares are manufactured in Butte from a clay quarried on Lost creek near the deposit worked by the Anaconda Copper Mining Co. A sample of this clay gives the following analysis:  $\text{SiO}_2$ , 72.8;  $\text{Fe}_2\text{O}_3$ , 3;  $\text{Al}_2\text{O}_3$ , 23.7 per cent.

Building brick are manufactured in all the largest cities of the State, the red surface clays being used in most cases, though shales suitable for the manufacture of paving brick are found in some localities and used for making building materials.

That the clay resources of the State have not been further developed is due largely to the fact that many of the deposits are at present inaccessible, but as the railroads branch out the conditions for exploitation become more favorable and these clays will be of commercial value.

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## The Tin Situation in Bolivia.

BY HOWLAND BANCROFT, DENVER, COLO.

(Butte Meeting, August, 1913.)

THIS article is not presented as a treatise on tin mines and mining in Bolivia. It deals primarily with the tin situation, and but fragmentary information is given regarding individual properties, generalizations being necessary in so short an article. Data on general subjects related to tin mining in Bolivia are necessarily abbreviated and very incomplete. It is believed that the references to be found in this article will help those interested to a more thorough understanding of the general conditions extant in Bolivia.

Bolivia produces from one-fifth to one-fourth of the world's supply of tin. The United States consumes about one-half of the world's supply and produces practically none. Tin ore is not reduced in the United States. These facts are not generally appreciated by American mining men. Many conflicting data have been published regarding tin in Bolivia. The *Transactions* of the Institute contain practically no mention of this subject.<sup>1</sup>

I have made a study of mines and mining conditions in the west coast republics of South America and have been particularly impressed by the possibilities of the Bolivian field.<sup>2</sup>

In consequence the thought seems justified that the present meeting would present a fitting occasion to bring the tin situation in Bolivia to the attention of American mining men.

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<sup>1</sup> Brief mention of tin in Bolivia will be found in A. F. Wendt's very interesting account of The Potosi, Bolivia, Silver District, *Trans.*, xix., 90 to 91 (1890-91).

<sup>2</sup> The possibilities of this field have caused others to write upon the subject, references to several publications appearing in this paper. However, in this article I have tried to present the subject with a view to showing the importance of the Bolivian tin field to the United States, this country being the largest user of tin in the world and up to the present is without a domestic supply. While the following presentation of the subject is in part a repetition of previously published material, it represents nevertheless the result of my own observations, combined, to some extent, with a compilation of data based upon the writings and statements of others.

## GENERAL STATEMENTS.

If the following facts are kept in mind in considering the tin situation in Bolivia the importance of the field to the people of the United States interested in mining will become very apparent.

1. As already stated, Bolivia produces from one-fifth to one-fourth of the world's supply of tin. This production comes from a comparatively few mines, the Bolivian tin industry being in its infancy. Fig. 1 shows the production of tin in Bolivia from 1897 to 1912. During this short period the output has increased from a little over 2,000 metric tons to more than 23,000 metric tons.

2. The United States consumes about one-half of the world's supply of tin, and the domestic production is negligible. Fig. 2 shows the increase in the importation of tin by the United States during the interval between 1897 and 1912. The imports have increased from 25,000 metric tons in 1897 to nearly twice that amount in 1912. This has been largely due to the flourishing condition of the American tin plate industry.

3. The consumption of tin is steadily increasing, as is also the production, the latter being due largely to the Bolivian supply. This increase in consumption and production has been accompanied by a steady increase in the price of tin, which has risen from 13 c. per pound in 1897 to 50 c. in 1912. To-day, tin is sold for  $\frac{1}{15}$  the price of silver. Fig. 2 shows the average monthly price of tin in New York from 1897 to 1912. The increased production, or the world's supply, of tin has been accompanied by a persistent rise in the price.

4. One-half of the world's supply of tin ore is controlled by Great Britain, and is smelted on British territory, the export of this proportion of tin ore being prohibited by reason of the high export tax on tin ore mined in the Malay Straits, British possessions. Fig. 1 shows the world's production of tin from 1897 to 1912. Bolivia's production is also platted for comparison. The production from Bolivia is approximately equivalent to the increase in the world's production.

5. Notwithstanding the consumption of one-half the world's supply of tin by the United States, capital from this country is not invested in tin properties and tin ore is not reduced in the United States. In consequence, by the purchase of one-half the world's supply of metallic tin the United States pays the entire profits resulting from mining and milling of one-half of all the tin ore mined, freight on ore to reduction works, reduction of ore to metallic tin, shipment of metallic tin to the United States, brokers' commissions, etc. Fig. 3 shows the value of the world's production of tin, the value of tin imported into the United States, and the value of the Bolivian tin production from



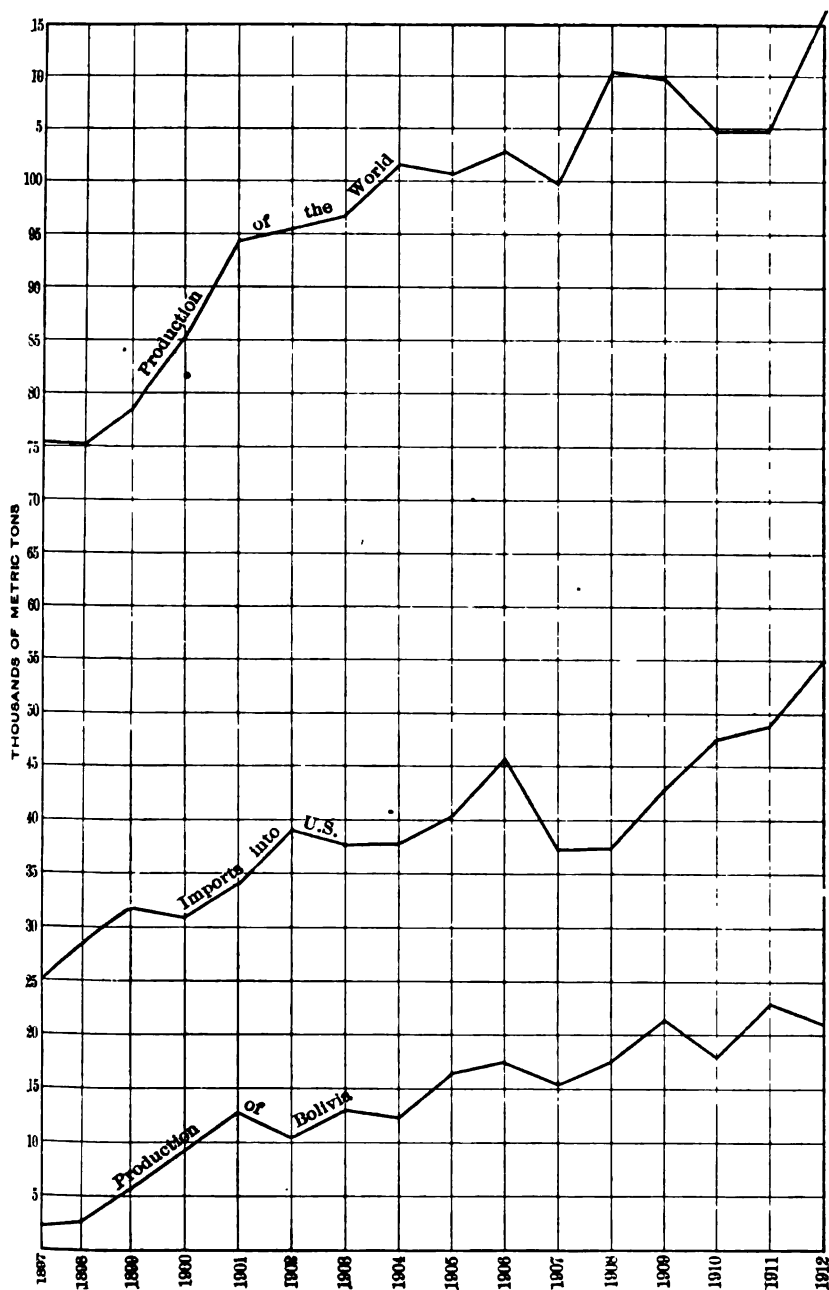


FIG. 1.—WORLD'S PRODUCTION OF TIN ; IMPORTS OF TIN INTO THE UNITED STATES ; AND PRODUCTION OF BOLIVIAN TIN, FROM 1897 TO 1912.

1897 to 1912. The total output has now reached a figure where the production is worth in round numbers \$100,000,000 annually.

6. As above stated, one-half of the world's production of tin ore is not available to purchase by nations other than Great Britain because of the high export duty on tin ore mined in the Malay Straits, British possessions. This leaves for purchase by the United States the tin ore mined in Banka, Billiton, Tongka Harbor, Australia, Africa, and Bolivia. The last named produces as much as all the others mentioned, is by far the most accessible country, and the completion of the Panama Canal will greatly facilitate American operations. The Bolivian mining laws are in many respects superior to those of the United States. The export tax on tin ore is graduated to comply with the market price of tin. For example:

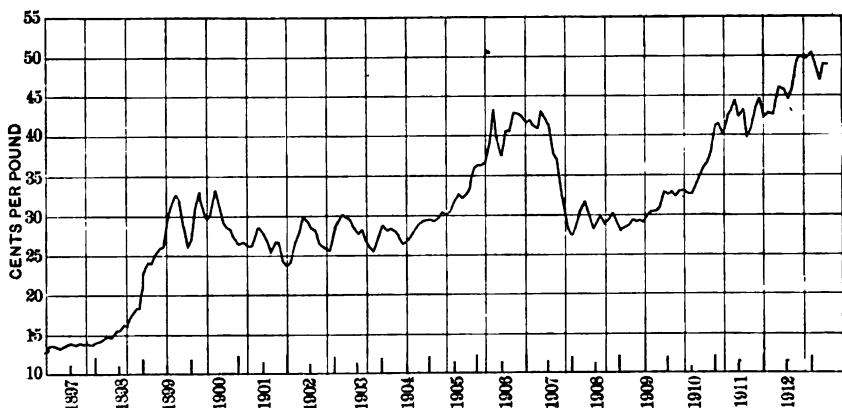


FIG. 2.—AVERAGE MONTHLY PRICE OF TIN IN NEW YORK FROM 1897 to 1912.

"The duties on tin are graded according to the London quotations for the bars of Straits tin, and rise from Bs. 0.90 for each 100 pounds when tin bars are quoted at £100 to Bs. 3.30 [Bs. 12.50 = £1 = \$4.8665 U. S. currency] if the price reaches £200 or more. These rates are for barilla of 60 per cent., but the bars of pure tin pay Bs. 1.80 for each 100 pounds when the London quotations for Straits tin is £100 a ton, and Bs. 4.20 if the price is over £200."<sup>3</sup>

Bolivia to-day ranks first among the tin lode mining countries, producing about four times as much tin from lode mines as Cornwall. In fact, one mine in Bolivia, La Salvadora, is credited with a yearly production equivalent to the total production of Cornwall. As is well known, the largest production of tin in the world comes from the Straits Settlements, this production combined with that from Banka and Billiton contributing two-thirds of the world's production

<sup>3</sup> From a pamphlet entitled *Bolivia*, published by the Bolivian Legation, Washington, D. C. (1912).

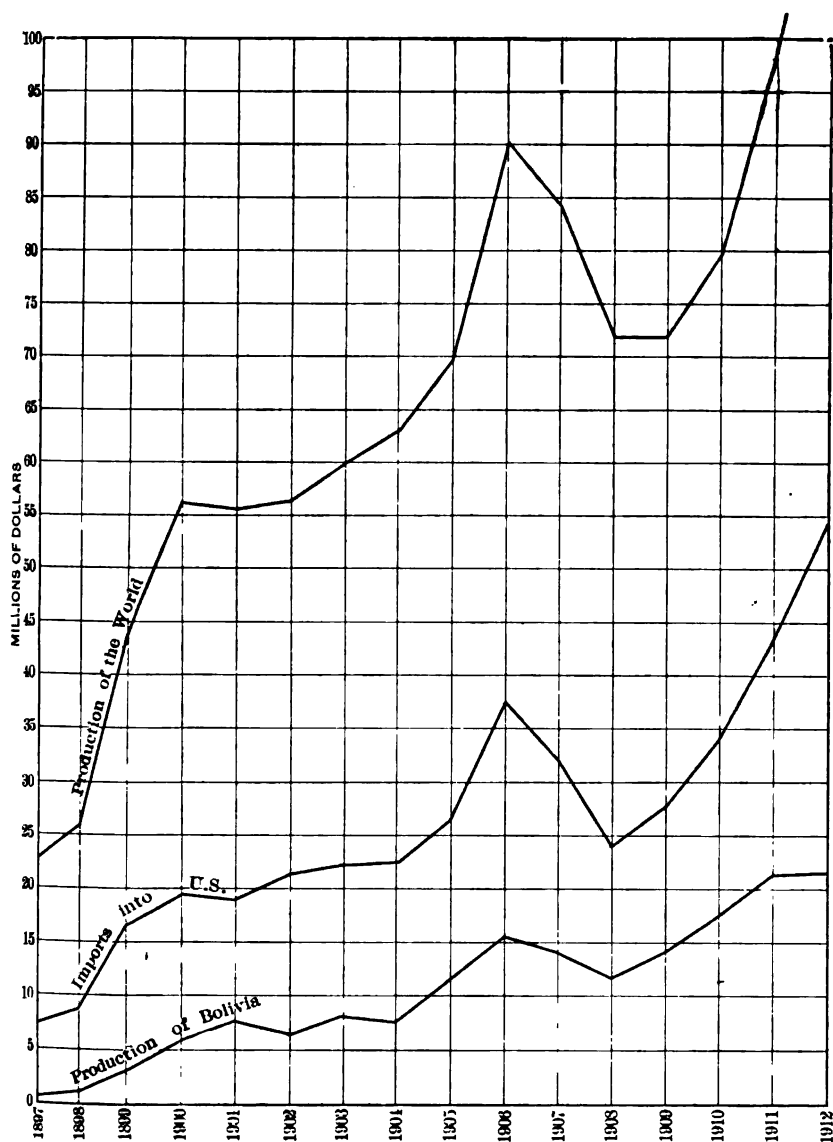


FIG. 3.—VALUE OF THE WORLD'S PRODUCTION OF TIN; VALUE OF THE TIN IMPORTED INTO THE UNITED STATES; VALUE OF THE BOLIVIAN TIN PRODUCTION, FROM 1897 TO 1912.

of tin. Australia, China, and Africa also contribute some tin. Individually, however, they are not at present important factors in the world's supply of this metal. It is to be remembered that all of the tin ore mined in the Straits Settlements, excepting about 3,000 tons produced yearly in the vicinity of Tongka Harbor by Australians, is subject to an export tax of  $33\frac{1}{3}$  per cent., this tax effectively keeping the tin ore in British hands until it has been smelted. Some of you will doubtless recall the attempt to operate a tin smelter at Bayonne, N. J., about seven years ago. This smelter was never blown in because the exports of Straits Settlements ore to other than British possessions was promptly forestalled by the enactment of the English export tax of  $33\frac{1}{3}$  per cent. Consequently the transports carrying oil from the United States to Asia were compelled to return without a cargo of tin ore from the Straits Settlements, which was contrary to the expectation of the interests concerned in building the tin smelter.

*Tin-Producing Area of Bolivia.*—It is to be remarked that Bolivia is the only country in South America producing tin ore in quantity, which seems strange in view of the fact that Peru,<sup>4</sup> Chile,<sup>5</sup> and Argentine<sup>6</sup> have many geologic relationships in common with those found in the tin-producing districts of Bolivia.

Tin ores are found in many localities in Bolivia, the principal producing properties being in the Departments of Oruro, Potosi, Cochabamba, and La Paz, the first two named being at present by far the most productive. These Departments cover roughly 100,000 square miles, most of which territory is mountainous, and all of which would be included in the so-called mineral belt of Bolivia.

Between the main ranges of the Andes broad flat pampas extend for many miles, the mean elevation of these being about 12,000 ft. above sea level. These pampas are bounded by north-south trending ranges of mountains, some of which rise to elevations of over 22,000 ft. above sea level, and throughout the mountain districts tin ores are found. In general, it may be said that the tin deposits which are

<sup>4</sup> T. Olaechea, commenting upon tin in Bolivia, says in *Boletín de Minas Industria y Construcciones*, Lima, 1902: "Although the metal referred to [tin] has only been known to exist in the Department of Puno [Peru], it will not be strange if some day, owing to the mineral wealth of the Peruvian soil, tin may be found as a result of new explorations, in conditions where it can be conveniently worked."

<sup>5</sup> A. Götting, *Zeitschrift für praktische Geologie*, June, 1894, pp. 224 to 230, states that cassiterite occurs in Chile in diabase in which are also deposits of cinnabar, siderite, etc. He states that the cassiterite does not appear to be commercial.

<sup>6</sup> H. D. Hoskold, in *Report upon the Mines, Mining, Metallurgy, and Mining Laws, etc., of the Argentine Republic*, Buenos Aires, 1904, states that stream and lode tin have been discovered in Argentine. (Thus far these deposits are not believed to have been proved commercial.—Author.)

being exploited occur between the elevations of 12,000 and 19,000 ft., deposits actually being worked at the latter altitude.

In this connection the following table may be of interest. This table is reproduced from an official publication by the Bolivian Government, *Monografía de la industria Minera en Bolivia*, by Pedro Aniceto Blanco, La Paz, Bolivia, 1910. Readers are cautioned not to take the information contained in the table too literally; for example, the tin content of the veins is greatly exaggerated. However, it represents a concise, though somewhat inaccurate, summary of a few of the features of some of the principal tin deposits of Bolivia.

*Generalized Summary of Features of Some of the Principal Tin Deposits in Bolivia.*

| Location.          | Name of the Mine.  | Number of Veins. | Strike.   | Dip.      | Country Rock.      | Per Cent. Tin. | Average Width of Vein. |
|--------------------|--------------------|------------------|-----------|-----------|--------------------|----------------|------------------------|
| Huanuni.....       | Cataricagua.....   | 1                | E. & W.   | 50° S.    | Porphyry           | 11½            | 1 meter                |
| Huanuni.....       | Barreno.....       | 1                | N. 75° E. | 80° S.    | Porphyry           | 11½            | 1 meter                |
| Huanuni.....       | San José.....      | 1                | N. 80° E. | 45° S.    | Porphyry           | 11½            | 1 meter                |
| Huanuni.....       | Dejada.....        | 1                | E. & W.   | 50° S.    | Porphyry           | 11½            | 1 meter                |
| Penny Duncan ..    | Vetilla.....       | 1                | E. & W.   | 70° S.    | Porphyry           | 11½            | 1 meter                |
| Penny Duncan ..    | Vetilla.....       | 1                | N. 70° E. | .....     | Porphyry           | 11½            | 1 meter                |
| Huanuni.....       | Various.....       | .....            | .....     | .....     | Porphyry           | 11½            | 1 meter                |
| Negro Pabellón...  | Negro Pabellón...  | 3                | N. & S.   | Vertical  | Slate              | 9½             | 0.08 cm. b             |
| Morococala.....    | .....              | 3                | .....     | Vertical  | Slate              | 10             | Variable               |
| Vilacollo.....     | Vilacollo.....     | 1                | E. & W.   | Vertical  | Porphyry           | 8              | Variable               |
| Colquiri.....      | Socobón Verde...   | 1                | .....     | Vertical  | Arenaceous shales  | 5              | 1.3 meters             |
| Tres Cruces.....   | Sayaquirá.....     | 1                | N. 80° E. | Vertical  | Slate              | 10             | 1 meter                |
| Oruro.....         | Various.....       | .....            | .....     | .....     | Porphyry           | 8              | Variable               |
| Challa-apacheta..  | Challa-apacheta..  | 1                | .....     | .....     | Porphyry           | 7              | Variable               |
| Challa grande..... | Avicaya.....       | 4                | N. 45° E. | Vertical  | Slate              | 8              | 1 meter                |
| Challa grande..... | Totoral.....       | 4                | N. 80° E. | 50° N.    | Porphyry           | 8              | 1 meter                |
| Chuncho.....       | Chuncho.....       | 3                | N. 80° E. | 50° N.    | Porphyry           | 8              | 1 meter                |
| Uncla.....         | La Salvadora.....  | 2                | N. 35° E. | N. 80° W. | Porphyry           | 17             | 0.8 meter              |
| Uncla.....         | Animas.....        | 1                | N. 40° E. | 74° W.    | Porphyry           | 15             | 0.8 meter              |
| Uncla.....         | San Miguel.....    | Various          | N. 40° E. | 70° W.    | Porphyry           | 15             | 0.8 meter              |
| Llallagua.....     | La Blanca.....     | 1                | N. 10° E. | .....     | Porphyry           | 15             | 0.5 meter              |
| Llallagua.....     | San Fermín.....    | 1                | N. 10° E. | .....     | Porphyry           | 15             | 0.5 meter              |
| Berenguela.....    | Various.....       | .....            | E. & W.   | .....     | Porphyry           | 9              | Variable               |
| La Paz.....        | Chacaltaya.....    | 1                | .....     | .....     | Porphyry and slate | 8              | Variable               |
| La Paz.....        | Milluni.....       | Various          | N. 50° W. | .....     | Porphyry and slate | 8              | 1 meter                |
| Chorolque.....     | Santa Bárbara..... | 1                | E. & W.   | Vertical  | Porphyry           | 9              | Variable               |
| Potosí.....        | Various.....       | .....            | .....     | .....     | Porphyry           | 10             | Variable               |

<sup>a</sup> Penny & Duncan is the name of a company, not a town. They are probably operating at Ventilla.

<sup>b</sup> This is probably a typographical error. The deposits at Negro Pabellón are known to be over 2 ft. wide.

*Production.*—Prior to 1899 Bolivia was not recognized as an important factor among tin-producing countries. For example, the production from Bolivia in 1883 was only 493 tons. The following year the production dropped to 204 tons, and it was not until 1888 that the annual production exceeded 1,000 tons.<sup>7</sup> From this time until 1898 the production fluctuated under 3,000 tons per annum. Since 1898 the production has been almost continuously increasing until in

<sup>7</sup> *Mineral Industry*, vol. i., p. 450 (1892).

1911 the production for the year reached 23,000 metric tons. See Fig. 1, compiled from data contained in different volumes of *Mineral Industry*. It is interesting to note in *Mineral Industry*, vol. ix., p. 639 (1900), the following statement: "Owing to lack of capital and facilities of transportation the industry is but little developed, and it is stated on good authority that the production could be easily doubled under more favorable conditions." Reference to Fig. 1 will show the 1900 production of Bolivia was nearly doubled in 1906 and nearly trebled in 1911.

*Climate.*<sup>8</sup>—Several distinct types of climate exist in Bolivia, depending largely upon altitude, though influenced to some extent by latitude. For the convenience of those unfamiliar with Bolivian conditions, the following table<sup>9</sup> is reproduced, which shows the several zones recognized in Bolivia:

| Zones.                 | Altitude.<br>Feet. | Mean<br>Tempera-<br>ture F. ° | Latitude<br>(South). | Tempera-<br>ture.<br>F. ° | Rainfall.<br>Inches. |
|------------------------|--------------------|-------------------------------|----------------------|---------------------------|----------------------|
| Snow Zone.....         | 16,404             | 34.4                          | 10                   | 90.82                     | 31.50                |
| Puna Brava.....        | 15,705             | 43.5                          | 15                   | 86.04                     | 30.79                |
| Puna.....              | 11,857             | 53.8                          | 20                   | 81.61                     | 30.08                |
| Cabecera de Valle..... | 10,043             | 59.4                          | 25                   | 76.82                     | 29.37                |
| Valle.....             | 8,202              | 64.2                          |                      |                           |                      |
| Yungas.....            | 5,538              | 69.8                          |                      |                           |                      |

As all of the tin properties are in the Puna or Puna Brava zones, we are concerned principally with the conditions in the higher regions. Two principal seasons are conspicuous there: the rainy season, which lasts from November until March, and the dry season, from April to October. These two seasons are not marked by any considerable change in temperature. Frequent rains also occur throughout the so-called dry season. In the higher regions of the Puna Brava no rain falls, the precipitation being in the form of hail or snow.

In general, it may be said that the climate of the Puna regions of Bolivia is good, while that of the Puna Brava zone is almost unendurable. Frequent wind storms and the terrific electrical storms that center about the higher mountain peaks of the Andes are exceedingly objectionable. The rare atmosphere extant at these higher altitudes is a serious hindrance to personal comfort and detracts materially from the efficiency of all operations.

<sup>8</sup> For a more complete account of the climatology of Bolivia, readers are referred to a publication of the International Bureau of American Republics, *Bolivia*, pp. 23 to 26 (Washington, D. C., 1904).

<sup>9</sup> *Sinopsis Estadística y Geográfica de la Republica de Bolivia* (La Paz, 1903).

*Vegetation.*—The Puna and Puna Brava zones are barren of a natural growth of trees and only small shrubs are present. Artificially planted eucalyptus trees flourish at altitudes of 12,000 ft. Because of their rapid growth, these trees would prove a salvation for future generations if planted in large numbers. Certain people have advocated the commercial possibilities of planting large groves of eucalyptus, to be cut when grown and used for railroad ties. Yareta (usually called a fungus), a resinous umbelliferous plant, forms one of the sources of fuel supply. The growth of this plant is slow, however, and as the consumption for use as fuel is high the supply is being rapidly depleted.

*Water.*—Properties situated near the snow line are peculiarly favored in one respect at least—they have an abundant supply of water. In general, water is scarce in the Puna regions of Bolivia. Nevertheless there are many running streams in Bolivia, and these afford ample water for concentration works as well as power for hydro-electric installations. Although water is not always conveniently near the tin properties, this is not by any means an insurmountable difficulty, for concentration works are built on the banks of the streams, or water is piped to the plants. Electricity is carried by high-power transmission lines from the source of supply and doubtless will play a much more important part in mining operations in Bolivia in the future than it has in the past.

*Transportation.*—The Departments of Oruro, Potosi, La Paz, and Cochabamba are traversed in places by railroad lines and the completion of railroads now building will greatly facilitate freight shipments. A few of the producers are well situated as regards transportation facilities, but the majority of the deposits are some distance from railroad shipping points, and the tin ore, in the form of barilla, has to be packed from these properties by llamas or mules to the nearest railroad point. These deposits are located in the outlying districts from 5 to 60 miles or more from any kind of a settlement. They represent, however, localities which are practically virgin, and are frequently the only mining locations within the immediate district. Tin ore from Potosi is smelted in water-jacketed furnaces and the impure tin resulting is exported in bars. This procedure saves freight, but yields a very impure product.

Freight rates on railroads in Bolivia are invariably high and are a serious drawback to greater profits resulting from mining operations. The completion of the new Arica á La Paz railroad may at least have the effect of reducing terminal rates.

Without rail connection or wagon roads all material has to be

transported on llamas or mules, and the operators located in out of the way places use this means for transportation of materials. Llamas will carry about 75 lb. and mules will carry from 200 to 300 lb. The former cost \$5 and the latter from \$30 to \$50, and the upkeep of the mules costs much more than for the llamas. During very dry weather this method of transportation is seriously interfered with.

*Power.*—Steam, generated by burning taquia, yareta, coal, or oil, is used for power in some of the plants. Because of the scarcity of fuel and consequently its high cost, various other means of generating power have been attempted. Anthracite gas-producer engines have been introduced and these have proved economical. According to J. B. Minchin,<sup>10</sup> the working cost of these engines is about 4c. per horse-power hour. Pelton water wheels and petroleum motors are also used. Electricity has been generated by gas engines and hydro-electric installations, this latter method of generating power being the real future for mining and milling operations in Bolivia. A successful electric furnace for smelting tin ores on the ground is not improbable, and the near future may see a revolution in the manner of handling the tin product of Bolivia.

*Fuel.*—The scarcity of fuel forms one of the chief difficulties in Bolivian mining. Australian coal costs about \$12.50 per ton at coast points. However, railroad freight rates from the ports to the interior are exorbitant and have the effect of raising the cost of coal by from \$20 to \$30 per ton by the time it reaches Bolivian railroad points. This makes the use of coal as a means for generating power almost prohibitive. Yareta, a resinous plant, and taquia (llama dung) are both used for fuel. The former costs about \$5 per metric ton and contains one-third the calorific power of coal. Taquia costs about \$5 per ton and contains one-sixth the calorific power of coal.

If the coals reported in the vicinity of Lake Titicaca develop into commercial deposits this local supply will greatly ameliorate the trouble arising from the present scarcity of fuel. The Peruvian oil fields represent a nearby source of supply of oil fuels. At La Fundicion, the smelter site of the Cerro de Pasco mines, located at an elevation of 14,100 ft., oil is used for fuel under the majority of the boilers, and it has there been found to be generally more efficient than coal. It is to be remembered that the efficiency of any power requiring oxygen in its generation should be figured about 3 per cent. less for every rise of 1,000 ft. above sea level.

*Labor.*—Native Indian labor of both sexes is used in the mines and

<sup>10</sup> Tin Mining in Bolivia, *Engineering and Mining Journal*, vol. lxxxi, No. 17, p. 810 (Apr. 28, 1906).



in the mills in Bolivia, with superintendents usually from the country whose citizens control the property. The wage scale varies from 40c. to \$2.40 per day for Indian labor, the average probably being about \$1 per day. The Indians are natural born miners and if the feast days were not of such frequent occurrence these laborers would prove very satisfactory. There is a scarcity of labor, this fact possibly accounting for the presence of many Indian women in the mines and mills of Bolivia. Mark R. Lamb<sup>11</sup> points out the necessity of care of future generations of Bolivian Indians, predicting that without this care the mines will have no native laborers within a few years.

#### MINING AND METALLURGY.

In general, the natural climatic conditions and high elevations that prevail in the Bolivian tin-mining districts do not tend to facilitate mining. The efficiency of human labor is reduced, as is also the efficiency of any power requiring oxygen in its generation. New mines do not appear to be sought and consequently are not found, regardless of the fact that the tin-mining country is barren of vegetation and consequently easy to prospect below the snow line.

Mining methods are almost universally crude, but few exceptions to this generalization existing in Bolivia. Up-to-date practice is almost unknown and the present efficiency of mining in Bolivian tin properties is consequently far from its possible maximum. By the installation of modern mining methods, the production and profits of many of the properties could be greatly increased and important mines developed from present day prospects. As an example of this the following statement may be of interest:<sup>12</sup>

[A mine in Oruro district]—"run at less than half capacity making £12,000 a year as profit where £100,000 might be made with modern methods and a capital expenditure of only £4,000."

Milling of Bolivian tin ore is more modernized than the mining methods there extant, and several complete up-to-date concentrating plants have been established at the more progressive properties.<sup>13</sup> In general, however, the tin ores are concentrated by hand, which consists of crushing by *quimbaletes* (rocking stones), and washing in moss-bottomed launders. Some of the more pretentious hand concentrating plants are equipped with *quimbaletes*, hand jigs, screens for

<sup>11</sup> Bolivian Tin Mining, *Engineering and Mining Journal*, vol. xciv., No. 26, p. 273 (Aug. 10, 1912).

<sup>12</sup> Present Position of Bolivian Tin Mines (extract from *Mining Journal*) *Mining World*, vol. xxx., No. 18, p. 829 (May 1, 1909).

<sup>13</sup> For a description and flow sheet of one of these the reader is referred to the *Mining Magazine*, vol. vi., No. 3, p. 208 (London, Mar., 1912).

sizing, *bubbles*, *bateas*, and canals. The hand concentrated tin ores are washed and rewashed until a 55 to 60 per cent. tin product is obtained.

At Potosi water-jacketed furnaces smelt the tin concentrates, a product containing many impurities resulting.

Generalizations regarding working costs are of little value and specific costs at one property are apt to be quite at variance with those at another. Nevertheless, the following fragmentary data on costs are given with the hope that they may prove somewhat serviceable. Assuredly some of the data will show comparative costs of production, and the probable profits resulting from operations under existing conditions. The total costs of mining, milling, freight, commissions, etc., are given by different operators as ranging from 14 c. to 38 c. per pound on European markets. Naturally so many diverse factors enter into the computation of costs at different locations that there result wide differences in total costs, and consequently in profits. One small company producing 40.57 tons of barilla per month from ore averaging 3 per cent. of tin reported a working cost at the mine of 17 c. per pound. Another company on a production of 2,000 tons showed a working cost at the mine of 7.5 c. per pound, on ore, four-fifths of which averaged 69 per cent. of tin.<sup>14</sup> Transportation by llamas is estimated<sup>15</sup> to cost 81 c. per ton-mile. J. B. Minchin<sup>16</sup> states the cost of transportation by llamas and donkeys at \$1.25 per ton-mile. Wire rope tramways installed at several properties have reduced the cost of carrying ores to 12 c. per ton-mile. The fuel problem has already been discussed. At present the most effective power generator seems to be the gas-producer engine. An 80-h.p. engine generates from 50 to 55 h.p. at 12,300 ft. above sea level and the consumption of anthracite is stated to be 1.54 lb.<sup>17</sup> per horsepower hour.<sup>18</sup> It is to be remembered that gas-producer engines are working very successfully on the poorest grade of coals. Consequently, if a local supply of coal could be obtained, no matter how poor in quality, it could be utilized in gas-producer engines to generate power. This would mean a large saving on the high cost

<sup>14</sup> Extract, British Consular Report, *Engineering and Mining Journal*, vol. lxxviii., No. 26, p. 1284 (Dec. 25, 1909).

<sup>15</sup> Present position of Bolivian Tin Mines (extract from *Mining Journal*), *Mining World*, vol. xxx., No. 18, p. 829 (May 1, 1909).

<sup>16</sup> Notes on Tin Mining in Bolivia. *Engineering and Mining Journal*, vol. lxxv., No. 1. p. 31 (Jan. 3, 1903).

<sup>17</sup> *Loc. cit.*

<sup>18</sup> With coal at \$40 per ton this would make the cost of the coal alone 3 c. per horsepower hour.

of imported anthracite. It is thought, as already stated, that electrical power represents the logical future power for Bolivian mining enterprises. Native labor is paid from 40 c. to \$2.40 per day, although much of the work is done by contract and has been found to be productive of larger results.

The following detailed cost sheets may be of interest.<sup>19</sup>

### 1. Mine with Hydraulic Motive Power.

|                                             | Cost Per Ton.<br>Bolivianos. |
|---------------------------------------------|------------------------------|
| Mining.....                                 | 8.60                         |
| Conveying from mines to mill.....           | 0.12                         |
| Salaries of chief miner and assistants..... | 1.00                         |
| Mine material, dynamite, etc.....           | 2.55                         |
| <b>Total mining.....</b>                    | <b>12.27</b>                 |
| Sorting, hand picking and handling.....     | 1.23                         |
| Milling.....                                | 0.95                         |
| Weighing, drying, bagging, etc.....         | 0.20                         |
| Material and repairs.....                   | 1.44                         |
| Assaying.....                               | 0.04                         |
| Millman and assistants.....                 | 1.24                         |
| <b>Total milling.....</b>                   | <b>5.10</b>                  |
| Manager, assistant, office, etc.....        | 0.78                         |
| Mine taxes.....                             | 0.14                         |
| <b>Total general expense.....</b>           | <b>0.92</b>                  |
| <b>Total cost.....</b>                      | <b>18.29</b>                 |

18.29 Bolivianos equal \$7.12 U. S. currency.

### 2. Mine with no Hydraulic Power. Fuel, Kerosene or Taquia.

|                                            | Cost Per Ton.<br>Bolivianos. |
|--------------------------------------------|------------------------------|
| Mining.....                                | 4.13                         |
| Materials, steel, dynamite, etc.....       | 1.26                         |
| Walling, filling.....                      | 1.60                         |
| <b>Total mining.....</b>                   | <b>6.99</b>                  |
| Fuel.....                                  | 1.00                         |
| Milling.....                               | 2.46                         |
| Drying barilla, bagging, etc.....          | 0.80                         |
| Materials, repairs, etc.....               | 0.50                         |
| Assaying.....                              | 0.10                         |
| <b>Total milling.....</b>                  | <b>4.86</b>                  |
| Carpenter, mason, blacksmith, foreman..... | 1.20                         |
| Accountant, storekeeper.....               | 0.40                         |
| Road repairing, legal services.....        | 0.30                         |
| Various incidentals.....                   | 0.40                         |
| <b>Total general expense.....</b>          | <b>2.30</b>                  |
| Manager and assistant.....                 | 1.60                         |
| Chief miner.....                           | 0.25                         |
| Various.....                               | 0.15                         |
| <b>Total administration.....</b>           | <b>2.00</b>                  |
| <b>Total cost.....</b>                     | <b>16.15</b>                 |

16.15 bolivianos equal \$6.29 U. S. currency.

|                                                                                            |         |
|--------------------------------------------------------------------------------------------|---------|
| Freight, duties, commissions, and insurance on concentrates from mine No. 1 to Europe..... | \$88.22 |
| Freight, duties, commissions, and insurance on concentrates from mine No. 2 to Europe..... | \$70.20 |

<sup>19</sup> These cost sheets are reproduced from an article by Miltiades Armas. Mining and Milling in Bolivia, *Engineering and Mining Journal*, vol. xcii., No. 9, p. 413 (Aug. 26, 1911).

GEOLOGY.<sup>20</sup>

So much has been written about the geology of Bolivian tin deposits that a repetition seems needless in a paper of this sort. Suffice to say that the tin deposits occur in five distinct types, which are, in the order of their commercial importance, as follows: 1. Deposits wholly within granular intrusive rocks, quartz-porphyry being the most conspicuous. 2. Deposits cutting both granular intrusive rocks of type 1 and metamorphic sedimentary rocks of type 3. 3. Deposits wholly within metamorphic sedimentary rocks, such as shales, slates, various schists, quartzites, etc. 4. Pegmatitic tin veins. 5. Stream tin placers.

The granular intrusive rocks of the quartz-porphyry type are believed to be of Mesozoic age. This quartz-porphyry, so conspicuous in many of the deposits in Bolivia, may represent a differentiation phase of granitic magmas. I am inclined to think that the andesites and trachytes referred to by Stelzner<sup>21</sup> have no genetic connection with the tin deposits of Bolivia, my views on this subject substantiating conclusions reached by Rumbold. (See reference to Rumbold, *Economic Geology*, Vol. 4, 1909.)

The metamorphic sedimentary shales, schists, quartzites, etc., are thought to be of middle Palæozoic age. Several writers have classed these rocks as Silurian, while others have termed them Devonian. Probably more detailed investigations will show several divisions of the Palæozoic represented by the metamorphic sedimentary series.

## ORE DEPOSITS.

In general, the deposits of tin ore in Bolivia occur in quartz veins in granular intrusive rocks which have invaded the metamorphic series of shales, quartz, mica and other schists, quartzites, limestones, dolomites, etc. In places the metamorphic series also contain mineralized veins where contiguous to granular intrusive masses. The mineralization in the latter class of deposits has been found to be disseminated, spreading out over a larger area of rocks and occupying small cracks, joints, and fissures in the metamorphic rock. This is particularly true of the type of deposit which occurs in both intrusive rock and metamorphic sedimentaries, the mineralization becoming

<sup>20</sup> For a more complete description of the geology and ore deposits of Bolivian tin properties, readers are referred to the Origin of Bolivian Tin Deposits, by W. R. Rumbold, *Economic Geology*, vol. iv., No. 4, p. 821 (June-July, 1909); and Genesis of Bolivian Tin Deposits, by Miltiades Armas, *Engineering and Mining Journal*, vol. xcii., No. 7, p. 311 (Aug. 12, 1911).

<sup>21</sup> Zinnerzlagertstätten von Bolivia. *Digest, Mineralogical Magazine and Journal of the Mineralogical Society*, London, vol. x., No. 47, p. 261 (Nov., 1893).

scattered as the deposit is worked out of the boundaries of the granular intrusive. While I did not examine any pegmatitic tin deposits in Bolivia, specimens shown me from deposits which I was invited to investigate left little doubt of the pegmatitic nature of the tin veins. Tin placer deposits are not being extensively worked in Bolivia and I did not examine any, although several were brought to my attention. As transportation facilities increase and the richer lode mines become exhausted, attention will doubtless be directed toward working placers known to exist in Bolivian tin fields.<sup>22</sup>

In width the lodes vary from a few inches up to several feet, the average being from 2 to 5 ft. wide. The length of the deposits along the strike of the veins varies considerably, some veins being traceable over several thousand feet while others appear to extend only a few hundred feet. The general idea that Bolivian tin deposits are superficial is erroneous, for veins have been proved to be commercially mineralized by tin ores to a depth of over 1,500 ft. below the apex. One ore shoot seen by me had been proved to a depth of 900 ft., to have a length along the strike of 360 ft., and to have an average width of 6 ft. of 15 per cent. tin ore. From several places in this ore shoot 60 per cent. tin ore was mined. These values are exceedingly above the average, however, the general run of mine ore in the tin properties in Bolivia being between 3 and 8 per cent. Armas<sup>23</sup> has stated that the average for all of the producing tin mines in Bolivia is 3 per cent.

In the lode mines, cassiterite forms the chief ore mineral. This is associated in places with highly argentiferous tetrahedrite, pyrite, chalcopyrite, and small quantities of the sulphides of tin, lead, zinc, antimony, molybdenum, and bismuth. Wolframite is also associated with the tin ores in places. In general, the silver values are associated with tetrahedrite, which seems to form a more conspicuous part of the vein filling when pyrite is present. The chief gangue mineral is quartz. With this is associated tourmaline, siderite, and brecciated country rock recemented by siliceous solutions. Fluorite has been reported<sup>24</sup> as occurring in some of the tin veins. Limonite is a conspicuous feature of the upper portions of the veins.

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<sup>22</sup> For a brief description of a tin placer deposit near Chorolque, readers are referred to an article by Malcolm Roberts, Chorolque Tin Mines and Alluvial Deposits, Bolivia, *Transactions of the Institution of Mining and Metallurgy*, vol. ix., pp. 372 to 375, vol. 9, London (1900-1901).

<sup>23</sup> Armas, Miltiades, "Mining and Milling in Bolivia," *Engineering and Mining Journal*, vol. xcii., No. 9, p. 412 (Aug. 26, 1911).

<sup>24</sup> Spencer, J. L., A description of the mineral specimens brought from Bolivia by Sir W. Martin Conway. See Conway, Sir W. Martin, *Climbing and Exploration in the Bolivian Andes*, p. 345 (Harper and Brothers, New York and London, 1901).

Bolivian lode deposits are believed to be the result of the after effects of igneous intrusion. The invariable association of granular intrusive rocks (of which quartz-porphyry is by far the most common) with or contiguous to the lodes, combined with the mineral associations in the veins, justifies the conclusion that the intrusive magmas and solutions accompanying or following the intrusions represent the source of the tin deposits, which were undoubtedly formed under great heat and pressure.

#### FUTURE OF THE BOLIVIAN TIN SITUATION.

Tin deposits are proved in Bolivia, and many mines doubtless await discovery. The principal difficulties which hinder developments are lack of adequate transportation facilities, lack of fuel, lack of sufficient labor, and more than all of these combined, the tremendous price at which productive properties are held. This last difficulty may be obviated by acquiring mere prospects, or investigating new ground only, which procedure has not been followed up to the present time. These difficulties, however, have not kept the production of the country from increasing from 2,000 tons in 1897 to over 23,000 tons in 1911. The Bolivian tin industry is still in its infancy, and offers large rewards<sup>25</sup> to those who are shrewd enough to see its

<sup>25</sup> D. H. Bradley, Jr., in an article entitled *Mining in Bolivia*, published in the *Mining Magazine*, vol. xi., No. 1 (New York, Jan., 1905), expresses the belief that Bolivian mines offer opportunities for investments paying 25 per cent. premiums within three or four years.

Mark R. Lamb, in an article entitled *Bolivian Tin Mining*, published in the *Engineering and Mining Journal*, vol. xciv., No. 8, p. 271 (Aug. 10, 1912), says that "A prospecting expedition would stand an excellent chance of success if properly equipped. . . . The opportunities for capital are numerous because there is little capital in the country."

Maurice Frochet, in *L'étain en Bolivie*, *Annales des Mines*, 9th ser., vol. xix., p. 186 (1901), asserts that "Tin veins close at hand are still untouched."

G. Preumont, writing on *The Bolivian Tin Mining Industries and Railways*, *London Mining Journal*, vol. lxxxiii. (1908), remarks, "Most of the mines are comparatively yet in virgin ground."

John Penberthy, of Redruth, Cornwall, is reported as having said to a correspondent of the *London Mining Journal* in 1906: "In time, however, the Bolivian output will become a very serious consideration, if not a preponderating factor in the world's supply. That time will come when railway facilities from the mines to both the Atlantic and Pacific seaboards make mining not only of high grade, but of the immense low grade deposits, at present untouched, a payable proposition."

An editorial in the *Engineering and Mining Journal*, Nov. 26, 1898, says: "Certainly it appears somewhat astonishing that America, after establishing a flourishing tin-plate industry, does not look for the raw material to its original sources."

W. R. Rumbold concludes his account of *The Origin of Bolivian Tin Deposits*, already referred to, with the following statement: "We all hope that the proposed new railway system now under construction by an American company will cheapen the cost of production, that the present mine owners will reduce their prices, and that foreign capital, modern machinery, and up-to-date managers will make what the writer [W. R. Rumbold] believes to be the richest mineral country in the world what it ought to be."

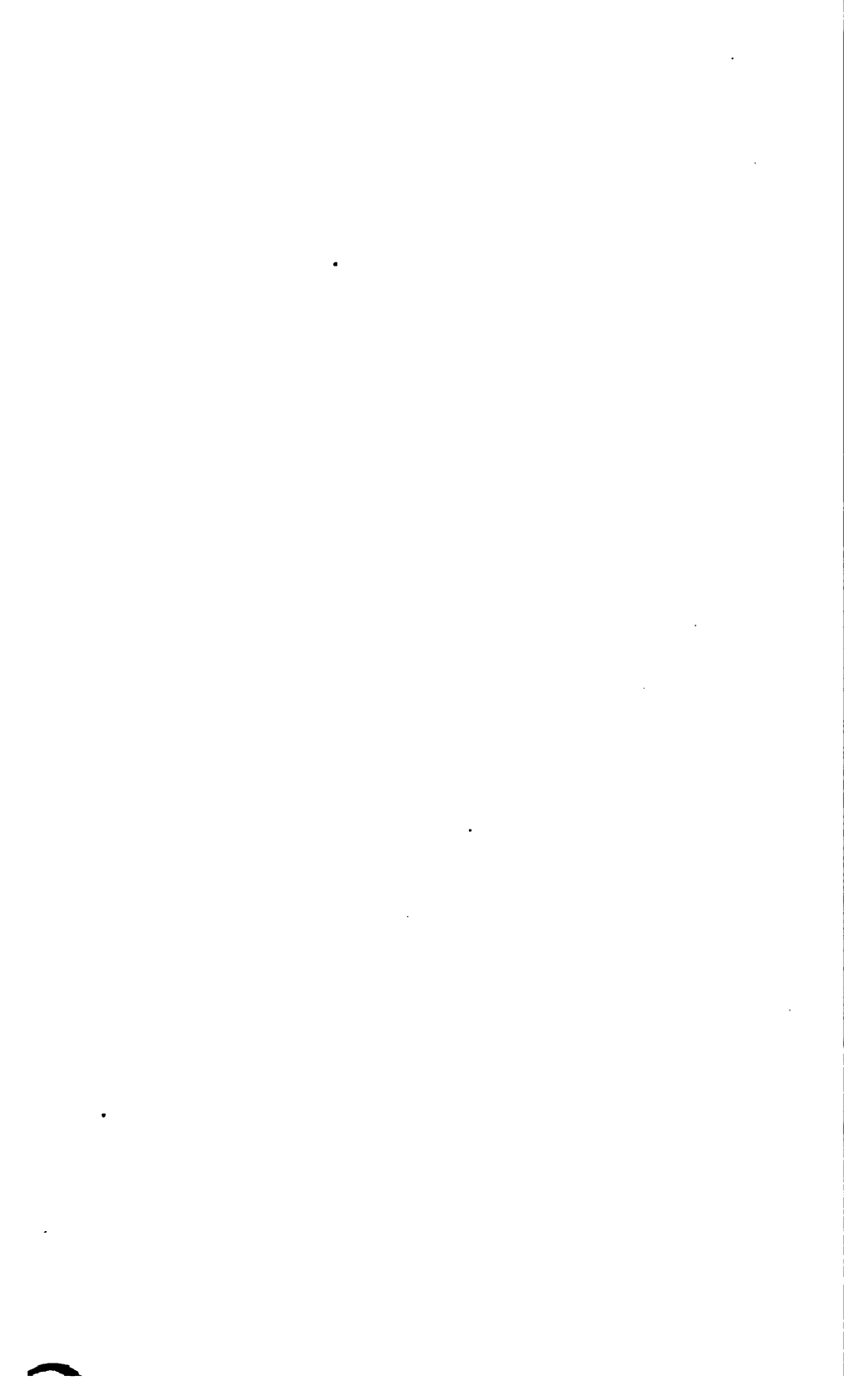
possibilities and who successfully overcome the difficulties consequent to mining in Bolivia, where I believe the tin situation deserves the attention of American mining men and capitalists.

#### LITERATURE.

For an extensive bibliography of the "Geology and Mineralogy of Tin," the readers are referred to the recent publication of that name prepared by Frank L. Hess and Eva Hess and issued by the Smithsonian Institution of Washington, D. C. In this volume are over 1,700 references to publications on tin, of which about 80 deal with some phase of tin in Bolivia. This publication, No. 1987 of the Smithsonian issues, will prove of immense value to any one interested in the literature of tin.

Attention is invited to the following publications on tin in Bolivia, some of these appearing in the bibliography above mentioned, which is somewhat amplified, containing brief mention of the contents of the publications listed.

1. Minchin, J. B.: Tin Mines of Bolivia, *Engineering and Mining Journal*, vol. li., No. 20, p. 586 (May 16, 1891).
2. Minchin, J. B.: The Mineral Resources of Bolivia, *Engineering*, vol. li., p. 453 (Apr. 17, 1891).
3. Stelzner, A. W.: Zinnerzlagertstätten von Bolivia, *Zeitschrift der deutschen geologischen Gesellschaft*, vol. xlv., p. 531 (1892).
4. Frochot, Maurice: L'étain en Bolivie, *Annales des Mines*, vol. xix. (1901).
5. Rumbold, W. R.: Origin of the Bolivian Tin Deposits, *Economic Geology*, vol. iv., No. 4, pp. 321 to 364 (June-July, 1909).
6. Blanco, Pedro Aniceto: *Monografía de la Industria Minera en Bolivia*, La Paz (1910).
7. Armas, Miltiades: Mining and Milling in Bolivia, *Engineering and Mining Journal*, vol. xcii, No. 9, p. 412 (Aug. 26, 1911).
8. Lamb, Mark R.: Bolivian Tin Mining, *Engineering and Mining Journal*, vol. xciv., No. 6, p. 271 (Aug. 10, 1912).
9. Bancroft, Howland: Mining on the West Coast of South America, *Mining and Scientific Press*, vol. cvi., No. 4, pp. 175 to 176 (Jan. 25, 1913).





DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Butte meeting, Aug. 18 to 21, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1913, when Vol. XLVI. of the *Transactions* will go to press. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## The Coal Fields of Montana.\*

BY EUGENE STEBINGER,† WASHINGTON, D. C.

(Butte Meeting, August, 1913.)

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\* Published with the permission of the Director of the U. S. Geological Survey. Many unpublished data from the files of the Geological Survey have been made use of in this paper, especially in the descriptions of some of the minor coal fields.

† Non-member.

## INTRODUCTION.

A LARGE number of papers and reports dealing with the coal fields of Montana have been published ‡ during the last 30 years, but the information is much scattered, appearing in many technical and scientific journals and in government reports, in many cases inaccessible to those most interested. In recent years, especially since 1905, our knowledge of the geology and coal contents of the important fields of the State has been much increased. Fairly specific and detailed information is at hand on all of the principal coal-bearing areas. The fields for which data are not at hand are small and inaccessible, and their omission will not materially affect an estimate of the coal resources of the State, viewed as a whole.

The paper here presented is a summary of existing information, all sources having been freely utilized in its preparation. The viewpoint adopted is that of the geologist, rather than that of the engineer or colliery operator, because by far the greater portion of the coal areas present have had only the most meager development, making information that will aid in prospecting and opening the at present little used coal lands of paramount importance to those interested in the coal fields of the State.

## POSITION OF MONTANA IN THE WESTERN COAL PROVINCES.

Conditions favorable to the accumulation of coal existed during Cretaceous and early Tertiary times in the United States between the 100th and 115th meridians, resulting in the accumulation of an extensive series of coal formations occupying a large part of the region between those meridians and extending from north to south entirely across the country and reaching far into Canada and New Mexico. The western half of this immense area of coal-bearing formations, soon after being deposited, was subject to the series of mountain-building movements which produced our present Rocky Mountain system. Because of these mountain-making disturbances and subsequent erosion, the coal formations originally more or less continuous in this area were isolated into a large number of detached basins. The area occupied by these basins has been called the Rocky Mountain coal province.

On the other hand, the coal-bearing formations laid down in the eastern one-half of the area lying between the 100th and 115th meridians were not disturbed by the orogenic movements producing the Rocky mountains and, where not covered by later deposits, are

‡ See list of literature at end of paper. Reference numbers in the text refer to this list.

now found lying almost horizontal over large areas in the northern Great Plains region and make up an immense continuous coal-bearing area that has been called the Northern Great Plains coal province. Montana contains a portion of each of these large coal provinces, the western part of the State, with numerous isolated coal basins making up a portion of the Rocky Mountain province, and the eastern part of the State making up a large unit area of the Northern Great Plains province. (See map, Pl. I.)

#### MONTANA'S TOTAL COAL TONNAGE.

Sufficient detailed geologic work has been done on the western coal fields during the last six or eight years to allow estimates to be made of the total coal tonnage in the important coal-bearing States. These results are shown graphically in Fig. 1, the fuels being classified into three grades, bituminous coal, sub-bituminous coal, and lignite. Montana, with a total of 380 billion short tons of bituminous coal, sub-bituminous coal, and lignite, ranks third in total coal tonnage, compared with the other States in the West. These results are especially interesting in view of the fact that earlier workers,<sup>32, 41</sup> basing their estimates on the probable areas underlain by coal-bearing formations in each of these States, place Montana first in a list of the coal-bearing States. North Dakota, with its immense tonnage of lignite, and Wyoming, with almost as great a tonnage of much higher grade fuel, each contains almost double the Montana tonnage, of which one-half is made up of lignite of the same grade as that found in North Dakota. If the grade of coal present be taken into consideration in the comparison of the coal resources of each of these States, Montana, with over one-half of its tonnage made up of lignite and only a very small proportion of the remainder consisting of true bituminous coal, should certainly rank below Colorado and Utah, both of which contain a very large tonnage of bituminous coal, and probably also below New Mexico, which contains twice Montana's tonnage of bituminous coal and a slightly larger tonnage of sub-bituminous coal. (See Fig. 1.)

#### THE COAL-BEARING FORMATIONS.

##### *General Statement.*

The coal-bearing formations of Montana range in age from Lower Cretaceous to mid-Tertiary, the oldest coal-bearing rocks being those of the Kootenai formations, which contain the coal horizon being mined in the Lewistown and Great Falls fields, and the youngest being the Tertiary lake beds, at present mined in the Drummond and Missoula fields.



The complete sequence of the coal-bearing formations in this State is shown in the generalized columnar section of the Cretaceous and Lower Tertiary rocks presented in Fig. 2. All of these formations are not present within any one field in the State, but the superposition of the various rock groups is definitely known because of the extensive geologic work that has been accomplished. Seven of the

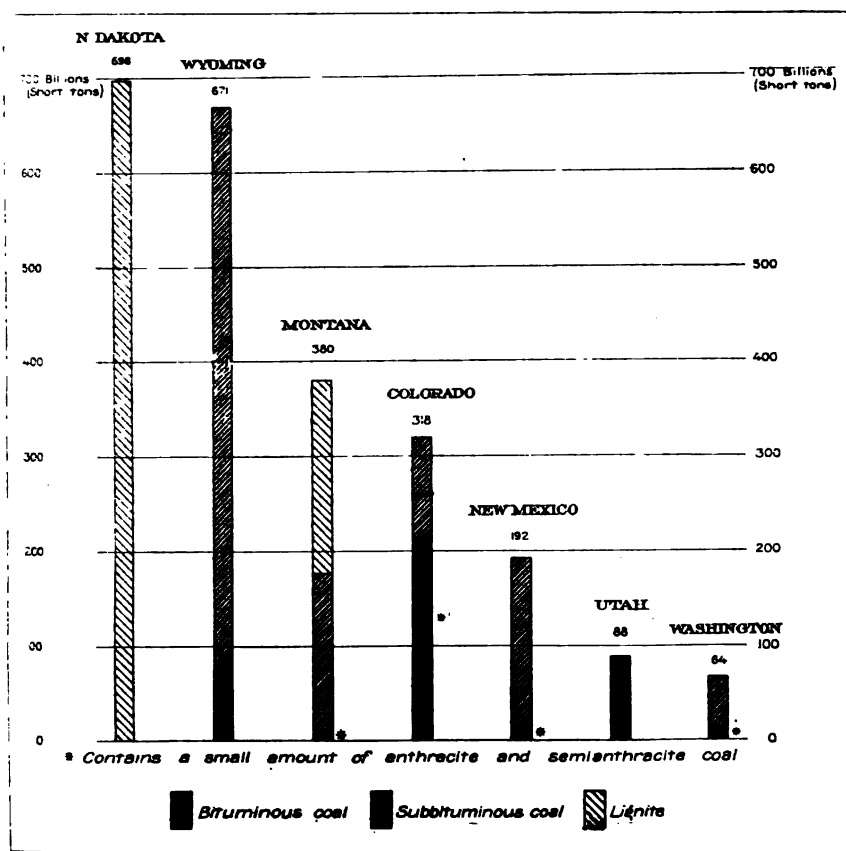
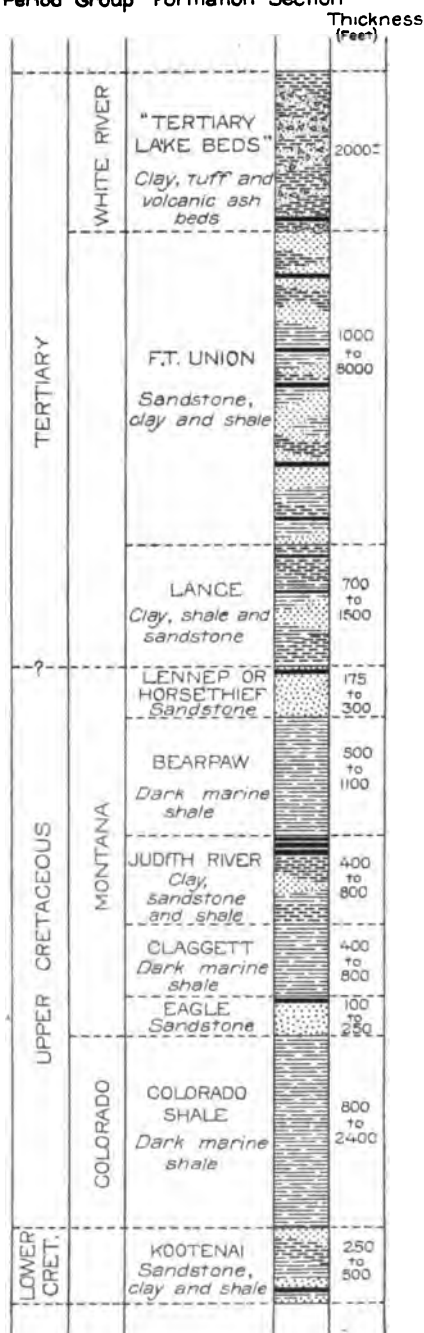


FIG. 1.—MONTANA TONNAGE OF ALL GRADES OF COAL AND LIGNITE COMPARED WITH THE TOTALS FOR OTHER WESTERN STATES. THE TOTALS ARE FOR WORKABLE COALS WITHIN 3,000 FT. OF THE SURFACE.

(From estimates by the Fuel Section of the U. S. Geological Survey, under the direction of M. R. Campbell.)

ten formations listed in this section, beginning with the Kootenai and ending with the Tertiary lake beds, are known to contain coal of commercial value in some parts of the State, but, on the other hand, not one of these seven contain workable coal in every locality in

Period Group Formation Section



Coal in the Drummond and Missoula fields, and in the other areas of Tertiary Lake beds in the mountains in the west half of the State occurs at this horizon.

Coals of the Red Lodge, Bull Mountain and Big Sandy fields and nearly all of the coals in the Eastern Plains region, occur in this formation.

A few thin and usually dirty coal beds occur at this horizon in the Bull Mountain field and in the Eastern Plains region.

Coal of the Blackfoot field, Teton county, occurs at this horizon.

Horizon of the coals of the Milk River field.

Horizon of the coal in the Bridger field, the Valier field and the approximate position of the coals mined in the Electric and Trail Creek fields.

Coal horizon of the Great Falls and Lewis-town fields.

FIG. 2.—GENERALIZED COLUMNAR SECTION OF THE CRETACEOUS AND TERTIARY FORMATIONS IN MONTANA, SHOWING THE STRATIGRAPHIC POSITIONS OF THE COAL HORIZONS IN THE VARIOUS COAL FIELDS.

which it is found. This uncertainty in the continuity of workable coal horizons is generally characteristic of a coal-bearing formation.

The formations that are not coal-bearing are the Colorado shale, the Claggett formation, and the Bearpaw shale, each of which is a dark gray marine shale, very similar lithologically. They are mainly of a marine character, this being proved by the abundance of ammonites, baculites, and other marine invertebrate fossils found in them. These marine shales mark three separate stages, separated by intervals in which the Eagle sandstone and Judith River formations, each containing a few coal beds, were deposited, during which all or a large part of the State was covered by the comparatively shallow marine waters of the ancient Cretaceous sea.

The principal lithologic characteristics and other stratigraphic details of the various coal-bearing formations, beginning with the oldest and crossing upward through the geologic time scale, are given below.

*Kootenai Formation*,<sup>3, 4, 14, 15, 22, 23.</sup>

The Kootenai formation is exposed in many parts of western Montana and is especially important in the Lewistown and Great Falls fields, because it contains the coal mined in those areas. Lying stratigraphically below a considerable thickness of Colorado shale, it is readily distinguished as a formation by the bright maroon-colored shales occurring throughout it and also by the prominent and frequently cross-bedded sandstones occurring in the lower part. The formation varies from 250 to 500 ft. in thickness in central Montana, while in the northwestern part of the State it is probably as much as 2,000 ft. thick. The typical development of this formation in the region in which it is coal-bearing is illustrated by the following section:

*Generalized Section of the Kootenai Rocks in the Lewistown Coal Field.*

|                                                                                                       | Feet. |
|-------------------------------------------------------------------------------------------------------|-------|
| (1) Shale, maroon, argillaceous, . . . . .                                                            | 200   |
| (2) Sandstone, grayish, coarse-grained, cross-bedded, . . . . .                                       | 8     |
| (3) Shale, maroon, argillaceous, . . . . .                                                            | 60    |
| (4) Sandstone, gray, coarse-grained, cross-bedded, . . . . .                                          | 25    |
| (5) Shale, maroon, argillaceous, . . . . .                                                            | 72    |
| (6) Sandstone, weathering soft gray, massive, coarse-grained to pebbly, . .                           | 50    |
| (7) Coal and coaly shale, . . . . .                                                                   | 10    |
| (8) Shale and sandstone alternating; the shale is sandy and the sandstone<br>thinly bedded, . . . . . | 87    |

The Lower Cretaceous age of the group of rocks making up this formation has been definitely determined by means of the abundant and well-preserved fossil-plants occurring throughout the strata, which

made it possible to correlate them with the Kootenai formation, as originally described by Dawson in Alberta. The rocks are all either of terrestrial or fresh-water origin, as is indicated both by the flora and by the few invertebrate fossils found.

Wherever the Kootenai formation contains workable coal in Montana the coal is found in a single bed occurring at one horizon lying between 60 and 90 ft. above the base of the formation. Immediately above this coal horizon there is generally found a massive, coarse-grained to pebbly sandstone, which, where the formation dips to an appreciable degree, weathers out as a prominent strike ledge, thus affording an excellent horizon marker to one prospecting for the coal.

*Eagle Sandstone*,<sup>6, 7, 25, 42, 44.</sup>

The coal in the Bridger field, in Carbon county, and that in the small area designated as the Valier field, in Teton county, occur in the Eagle sandstone. In the Electric and Trail Creek fields the various formations belonging to the Montana group of the Upper Cretaceous can not be sharply differentiated, but the coal being mined there is found at a position approximating that of the horizon in the upper part of the Eagle sandstone.

Where it is typically developed, as on the Missouri river near the mouth of Eagle creek, where it forms the prominent landmark known as the "Stone Walls of the Missouri," the formation is characterized by a massive gray to whitish gray sandstone. Its position above the dark bluish gray Colorado shale and the prominence of its main sandstone member make the formation easily recognizable, although the fossils found are of little value for purposes of correlation. In the Valier field the coal in the Eagle lies at the top of the formation and is present in a single workable bed, while in the Bridger field it occurs in three beds, separated by massive sandstone members from 35 to 75 ft. thick.

The Eagle sandstone has been recognized at many other localities over a wide area in the western part of the State, notably (1) in the upper part of the Musselshell valley north of the Crazy mountains,<sup>42</sup> (2) in the lower Musselshell valley north of the Bull mountains, and (3) in Teton county over an area extending from Chouteau northward to the international boundary, and, although thin coals are occasionally found in these localities, the presence of coals of commercial value is very doubtful.

*Judith River Formation*,<sup>25, 26, 42.</sup>

The Judith River formation is coal-bearing to a commercial extent in two localities in Montana, the first in the Milk River field in Chou-



teau county in the northern part of the State, and the second just to the south of the above area along the Missouri river in the vicinity of the Judith basin. In its typical development, the Judith river is almost entirely a fresh-water formation. It overlies the marine Claggett shales conformably and is composed of alternating light-colored beds of sandstone and shale, having an average thickness of 380 ft. A few brackish water beds occur near the top of the formation in a transition zone grading into the marine shales of the Bearpaw lying above. There is no persistent member in the entire formation which can be followed any great distance, the occasional beds of massive sandstone present grading rapidly along the outcrops into soft shale or friable sandstone. In the same manner a coal bed of workable thickness which may be present at one locality may pinch out altogether and be replaced by carbonaceous shale at the next exposure half a mile away.

All of the workable coals found in the Judith River formation occur within the upper 150 ft. As many as four beds have been found at a single locality at intervals of from 10 to 30 ft. apart, but usually only one is found. The beds are very lenticular and show considerable variation in thickness when traced on the outcrop. The Judith River formation has been studied over nearly the entire length of the Musselshell valley in the central part of the State, but was not found to contain coals of importance in any of this area.

*Horsethief or Lennep Sandstone,*<sup>42.</sup>

Overlying the Bearpaw shale wherever the beds are not eroded away, there is generally found a sandy formation more or less similar to the Eagle sandstone, and, like it, containing a few thin coals in its upper portion over widely scattered localities. The most important coal occurrence associated with this sandstone is in the Blackfoot field in Teton county in the northern part of the State, where coal is found outcropping at intervals, along a tract about 15 miles in extent. The formation is made up almost entirely of a massive gray sandstone, varying from 175 to 300 ft. in thickness and containing a single non-persistent coal horizon at the top. This sandstone formation also outcrops in the part of the Musselshell valley lying immediately north of the Crazy mountains, where it is known as the Lennep sandstone. It is not coal-bearing in this latter area.

*Lance Formation,*<sup>5, 8, 16, 21, 37, 54.</sup>

The Lance formation is of small importance as a coal-bearing formation in Montana. It forms the western border of the large

area making up the lignite and sub-bituminous coal region in the eastern part of the State. A large part of this border is mapped as being doubtfully coal-bearing because of the very uncertain nature of the Lance coals contained in it. The exact age of the Lance has been in dispute for many years. The fossil flora found in the rocks indicates a Tertiary age for this formation, while the invertebrate fauna is closely allied to similar forms found in the Cretaceous. The formation consists of a variable thickness of lenticular beds of soft clays, shales, and sandstones, and is generally distinguishable from the formations lying above and below it by its sombre-colored hues, in recognition of which the formation has often been termed "Sombre Beds."<sup>8</sup> The few coals contained in it are found in the upper part of the formation and are thin, lenticular, and generally very dirty.

*Fort Union Formation*,<sup>1, 2, 5, 8, 9, 12, 16, 37, 39, 40, 53, 54.</sup>

About 90 per cent. of the total tonnage of lignite and coal found in Montana occurs in the Fort Union formation, making it by far the most important of the rock groups under consideration. It contains practically all of the coal in the Bull Mountain field, the Red Lodge field, the Big Sandy field, Chouteau county, and in the immense coal area in the Eastern Plains region. The only known locality where rocks occupying this position in the stratigraphic column in Montana do not contain workable coals is in Teton county in the northwest part of the State, where only a few very thin and scattered coals occur.

The Fort Union formation consists of a variable thickness of yellowish-grayish sands and sandstones, often in quite massive beds, interbedded with gray clays and coals. The sands and sandstones predominate. In the eastern part of the State it is not much over 1,000 ft. in thickness, but in going westward toward the mountains it thickens until, in the Red Lodge field, it is 8,500 ft. thick. A very complete and well-preserved fossil flora is found in these rocks, which places their age as basal Tertiary. Leaves from broad-leaved trees, very similar to present existing species, are the most common forms met with.

The number of coal beds and the total amount of coal found in this formation are phenomenal. In the Bull Mountain field 24 beds were found at as many different horizons in a total thickness of 1,650 ft. of strata. The general habit of the beds is lenticular, although several of the coals are notable exceptions to this rule, and it has been possible to trace their outcrop for many miles. In the Eastern Plains region the coal beds are equally as numerous and, on the

average, rather thicker than in the Bull Mountain field. In Dawson county, on the Yellowstone river, a section across 980 ft. of this formation contains 11 lignite beds totaling 49 ft. in thickness, giving a ratio of 1 ft. of lignite for every 20 ft. of rocks. This is about double the amount of coal per unit of formation found in the eastern coal measured, and justly entitles the Fort Union to be termed a "coal age," as well as a Carboniferous period in Palæozoic time.

### *Tertiary Lake Beds.*

The coals in the Missoula and Drummond fields, and numerous smaller areas in the mountains of western Montana, occur in the Tertiary lake beds, which are the youngest coal-bearing rocks in the State. They have been determined to be approximately Oligocene or mid-Tertiary in age by means of the vertebrate fossils contained in them or in immediately associated rocks. They are made up mainly of massive slightly indurated tuff composed in part of clay, the prevailing colors being light shades of cream and gray. They also contain occasional beds of fairly pure volcanic ash, and also impure fresh-water limestones. The coal found in these beds seems to occur only at horizons near the base of the formation.

### DISTRIBUTION OF THE COAL FIELDS.

The widespread distribution of lands containing coal in Montana is strikingly shown by the map of the coal fields of the State (Pl. I.). Coal fields of greater or less size are found in every part of the State, so that there is no point in it that is more than 75 miles from an area containing workable coal. The largest single area present is the lignite and sub-bituminous coal region in the eastern part of the State, covering a large part of Custer, Dawson, and Valley counties, and extending entirely across the State in a north-south direction, with a maximum width of 160 miles. This immense area is estimated to contain 365 of the total 380 billion short tons of coal and lignite occurring in Montana. A graphic representation of the tonnage present in this region compared with other important fields in the State is shown in the diagram on Plate I. The next important field in point of contained tonnage is the Bull Mountain field, with the estimated total of a little over four billion tons of sub-bituminous coal. None of the remaining contains more than three billion tons of workable coal. Because of their proximity to means of transportation, the Bridger, Red Lodge, and Trail Creek fields, which are comparatively unimportant when the total coal tonnage of the State is considered, have, up to the present time, furnished the greater part of the coal

mined in Montana. The immense quantities of fuel found elsewhere remain practically undeveloped.

The central part of the State, going from south to north, contains, first, near the southern border, a group of comparatively small fields including the Bridger, Red Lodge, Stillwater, Trail Creek, Electric, Gallatin, and Lombard fields. Farther north, in the middle part of the State, lie the Bull Mountain, Lewistown, and Great Falls fields, all of which are much larger in area than the fields lying farther south, while still farther north lies the Milk River field, bordering on the international boundary. The Big Sandy field, and an unnamed area occupying the region along the Missouri river, lies between the Lewistown and Milk River fields.

The western part of Montana, which lies mainly within the Rocky mountains, is dotted with numerous small isolated coal fields which have undergone little or no development and concerning which very little detailed information has been published. The most important group of these, which includes the Drummond and Missoula fields, covers nearly all of the southwest corner of the State, all of the coals present being found in the Tertiary lake beds. To the north near the international boundary are found the Valier, Blackfoot, and Glacier Park fields, besides several other small and unimportant areas.

#### CLASSIFICATION OF MONTANA COALS.

##### *General Statements.*

On the map presented with this paper the coals found in Montana are classified into three grades, lignite, sub-bituminous coal, and bituminous coal, while a fourth type present in the Gallatin field is indicated as probably semi-anthracite or semi-bituminous coal, the exact determination being left in doubt because of the lack of information concerning the fuel found there.

The classification of bituminous coals and the coals of lower than bituminous grade, which form by far the greater part of the total coals found in Montana, has always been a very difficult question, for these various types of fuels grade imperceptibly into one another, there being no natural line of separation between them. Chemical analyses alone are not adequate, for the differences between the various grades are physical as well as chemical, so that no scheme of classification based entirely on chemical analyses will be completely successful. As a rule, the lower-grade coals contain much more moisture than those of the bituminous class, but the moisture content of individual samples varies so irregularly and depends so much upon the condition of the mine sampling that it is not an entirely safe criterion

on which to base distinctions, but if the averages of a large number of samples from each type of coal be compared, all the coals being sampled in the same manner, the moisture content of the lower-grade fuels is distinctly higher than that of the higher-grade coals.

An excellent criterion for separating the high-grade coals from those poorer in quality, which can be depended upon more than any other, is the manner of weathering, especially in the fracturing developed in the coal as it gradually dries. In bituminous coals the fractures thus developed will correspond with the cleavage and the resulting fragments will remain prismatic in shape, even to the finest dust particles. On the other hand, the lower-grade coals will check and fracture irregularly, and the resulting fragments will be irregular in outline.

By using the above criteria, a large group of low-grade coals which are very black and frequently of brilliant luster, with fairly well developed cleavage, thus closely resembling true bituminous coals on casual examination, have been separated from the class of bituminous coals, and the term "sub-bituminous" applied to them. About 45 per cent. of the total coal tonnage of Montana consists of this type of coal, which is often called "black lignite" or "lignitic" coal; but the term "lignite" or "lignitic" is not appropriate, for the reason that in no sense are these coals woody, as is implied by the term "lignite." The west one-half of the Eastern Plains region, the Bull Mountain field, Milk River field, and Red Lodge field, all contain this type of coal, while the Great Falls, Lewistown, Bridger, Trail Creek, and Electric fields are the principal areas supplying coal that is truly bituminous in grade. True lignite, which is brown, lusterless, and distinctly woody in texture, occurs only along the eastern border of the State, making up over one-half of the tonnage estimated to be present in the Eastern Plains region.

#### *Comparison of Chemical Analyses and Heating Values.*

A comparison of chemical analyses and heating values of coals from 11 of the more important Montana coal fields and of coals from six other fields lying outside of the State, which either come into direct competition with the Montana coals or are accepted standards in the coal trade, is shown in Fig. 3. Proximate analyses giving the ash, fixed carbon, volatile matter, and moisture content of the coals, together with sulphur determinations, are used for a comparison of the chemical character of the various fuels, Table I. The heating value recorded in British thermal units is given in two forms, one for the air-dried sample, which very closely represents the coal as received by the consumer, after drying during shipment and while

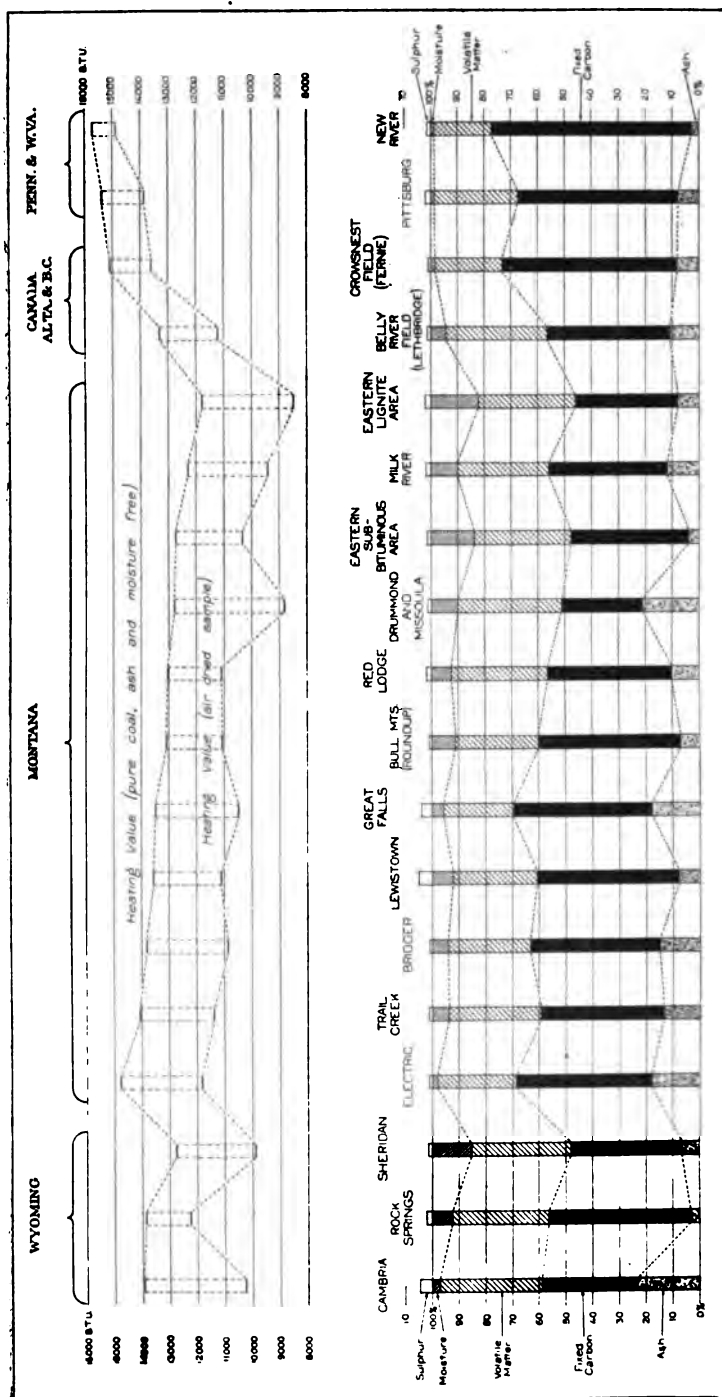


FIG. 3.—HEATING VALUE, PROXIMATE ANALYSES ON AIR-DRIED BASIS, AND SULPHUR CONTENTS OF MONTANA COALS COMPARED WITH COALS FROM ADJACENT COAL-PRODUCING REGIONS IN WYOMING AND CANADA, AND WITH STANDARD EASTERN COALS.

The results presented are averages of a number of samples taken from all parts of each field. (From analyses by the U. S. Geological Survey, U. S. Bureau of Mines, and Department of Mines, Canada.)

being held in stock, and the other for theoretically pure coal from which the ash and moisture content have been removed, obtained by recalculating the results of the determination on an air-dried basis. This second value fairly represents the relative value of the fuel constituents of each of the coals taken alone and is a true measure of the degree of advancement each coal has attained in the process of transformation from original vegetable matter into coal. In every case the results represent the averages obtained from a large number of analyses of coals from all parts of each field and are believed thoroughly to represent the average of the coal that can be produced. All of the analyses and the procedure followed on sampling were made under identical standards, with the exception of the two Canadian coals, which were sampled and analyzed under standards slightly different from those used in the United States, but not different enough to affect the results.

TABLE I.—*Heating Values, Proximate Analyses on Air-Dried Basis, and Sulphur Contents of Montana Coals, Compared with Coals from Adjacent Coal-Producing Regions in Wyoming and Canada, and With Standard Eastern Coals.*

(From analyses by the U. S. Geological Survey, U. S. Bureau of Mines, and Department of Mines, Canada.)

| State                                  | Field.                       | Moisture. | Volatile Matter. | Fixed Carbon. | Ash. | Sulphur. | B.t.u. | B.t.u. (Pure Coal—Ash and Moisture Free.) |
|----------------------------------------|------------------------------|-----------|------------------|---------------|------|----------|--------|-------------------------------------------|
| Wyoming.                               | Cambria.....                 | 3.6       | 37.9             | 35.3          | 23.3 | 4.5      | 10,220 | 13,990                                    |
|                                        | Rock Springs.....            | 8.2       | 36.0             | 51.9          | 3.8  | 1.1      | 12,230 | 13,910                                    |
|                                        | Sheridan.....                | 15.8      | 37.4             | 40.7          | 6.1  | 0.8      | 9,980  | 12,780                                    |
| Montana.                               | Electric.....                | 2.4       | 29.3             | 50.3          | 17.9 | 0.7      | 11,800 | 14,820                                    |
|                                        | Trail Creek.....             | 5.6       | 34.9             | 45.4          | 14.1 | 0.5      | 11,390 | 14,120                                    |
|                                        | Bridger.....                 | 5.8       | 31.1             | 47.6          | 15.4 | 0.6      | 10,870 | 13,820                                    |
|                                        | Lewistown.....               | 7.6       | 30.2             | 51.9          | 9.8  | 3.9      | 11,040 | 13,640                                    |
|                                        | Great Falls.....             | 4.1       | 26.7             | 50.8          | 18.4 | 2.9      | 10,440 | 13,580                                    |
|                                        | Bull Mountain (Roundup)...   | 9.4       | 31.2             | 52.8          | 6.6  | 0.5      | 11,070 | 13,180                                    |
|                                        | Red Lodge.....               | 6.7       | 36.6             | 46.6          | 10.2 | 2.1      | 11,060 | 13,120                                    |
|                                        | Drummond and Missoula.....   | 10.6      | 38.3             | 29.9          | 21.2 | 1.3      | 8,810  | 12,890                                    |
|                                        | Eastern sub-bituminous area. | 16.4      | 35.9             | 43.2          | 4.5  | 0.6      | 10,250 | 12,850                                    |
|                                        | Milk River.....              | 10.1      | 34.0             | 43.3          | 12.6 | 0.8      | 9,400  | 12,350                                    |
|                                        | Eastern lignite area.....    | 19.0      | 35.6             | 37.0          | 8.4  | 1.1      | 8,510  | 11,820                                    |
| Canada, Alberta and British Columbia.  | Belly River (Lethbridge).... | 9.3       | 38.0             | 45.7          | 12.3 | 1.0      | 11,200 | 13,305                                    |
|                                        | Crowsnest (Ferne).....       | 1.9       | 25.1             | 64.9          | 9.9  | 0.5      | 13,650 | 15,070                                    |
| Pennsylvania, West Virginia, and Ohio. | Pittsburg.....               | 1.3       | 31.6             | 58.7          | 8.5  | 1.5      | 13,920 | 15,410                                    |
|                                        | New River.....               | 0.8       | 21.1             | 74.2          | 3.9  | 1.2      | 14,980 | 15,710                                    |

The arrangement of the coals on the diagram presented in Fig. 3, comparing the coals from the various Montana fields, is determined by the relative heating values of the theoretically pure coal—ash and moisture free—which, as stated above, is believed to be a true measure of the relative degree of coalification attained by the different fuels. Considered on this basis, the coals, as arranged, show a fairly equable gradation in values from 14,820 B.t.u. for the Electric field, which stands first on the list, to a value of 11,820 B.t.u. for the lignite from the Eastern Plains region, which stands last, the most rapid drop in the gradation being from 14,820 B.t.u. for the Electric field to 14,120 for the Trail Creek coals, showing that the coal of the Electric field stands easily above all of the other coals of Montana in the degree of coalification attained. On this basis, going from the highest grade downward, the bituminous coals of the State rank as follows: (1) Electric field, (2) Trail Creek field, (3) Bridger field, (4) Lewistown field, (5) Great Falls field.

Among the coals of the sub-bituminous class, the Bull Mountain coal ranks first, followed in the order named by the coals from the Red Lodge, Drummond, and Missoula, Eastern Plains region, and Milk River fields, which are in turn followed by the lignite from the Eastern Plains region.

On the other hand, if these coals are compared on the basis of the heating values of the air-dried sample, which more nearly represents the coal as used by the consumer, several striking exceptions to the above appear, which in every case seem to be explained by examining the ash contents of the coals in question. The ash simply occupies the place of combustible matter and thus exerts a purely negative value on the fuel. This is probably better illustrated by comparing the averages shown on the diagram obtained by the Cambria and Rock Springs coals from Wyoming than by any coals in Montana. On comparing the heating value of the ash and moisture free coal, the Cambria ranks above the Rock Springs, although its heating value on the air-dried basis is only 10,220 B.t.u., compared with 12,230 for the Rock Springs coal, the difference being due to an ash content of 23.3 per cent., as compared with 3.8 in the Rock Springs coal. The first change to be made in the order of the Montana coals on this basis is that the coal for the Lewistown field, averaging a greater heating value, should be placed above the Bridger coal, because of an ash content of 9.8 per cent. for the former, against 15.4 per cent. for the latter. Again, the Bull Mountain and Red Lodge coals, both of which belong to the sub-bituminous class on the basis of their B.t.u. values for an air-dried sample, rank distinctly above



the Great Falls and Bridger coals, the difference again being due to the varying ash content. The last example is shown by the averages for the coals of the Drummond and Missoula field, which should rank below the sub-bituminous coal, both from the Eastern Plains region and the Milk River field, because of the very high ash percentage, 21.2, found in them.

On studying the moisture content of the Montana coals, it soon becomes evident that the arrangement of the coals inversely according to percentage of moisture in them, would agree in a general way with the arrangement as determined by the heating values of the pure coal—ash and moisture free. The coals of the Electric field show the lowest moisture content, and the lignite of the Eastern Plains region the highest.

On comparing the Montana bituminous coals with those from nearby States, it is seen that both the Electric and Trail Creek coals have heating values for theoretically pure fuel in excess of either the Cambria or Rock Springs coal from Wyoming, but, on the other hand, the low percentage of ash in the Rock Springs coal gives it a much higher heating value on the air-dried basis than any of the bituminous coals in Montana. The sub-bituminous coal from the Bull Mountain and Red Lodge fields easily ranks with or above the coal from the Sheridan field in Wyoming, which is more truly comparable with the sub-bituminous coals from the Montana Eastern Plains region.

On comparing the Montana coals with those from adjacent fields in Canada, it is evident that the coals from the Belly River field (Lethbridge) compare favorably with the Bridger and Lethbridge coals, but are not equal to the Electric and Trail Creek coals. None of the Montana fuels can compare with the high-grade coal found in the Crowsnest field in British Columbia and Alberta, while on the other hand the standard coals from Pennsylvania and West Virginia are seen to excel all other coals whose averages are shown.

#### DESCRIPTIONS OF THE COAL FIELDS.

##### *Fields Containing Bituminous and Higher-Grade Coals.*

*Bridger Field.*<sup>11, 44</sup>—The Bridger field is located in Carbon county in the southern part of the State and occupies a long narrow area extending northwest from near the State line in T. 9 S., R. 22 E., across the Clark fork of the Yellowstone and Rock creek for about 35 miles. Considerable development has been accomplished in the northern part of the field, centering around the towns of Bridger, Coalville, and Joliet. It is estimated to contain about 120 sq. miles

of area underlain by coals of workable thickness within minable depth.

The Eagle sandstone and associated formations, consisting of the Colorado shale below and the Claggett shale and sandy brackish-water beds above, outcrop across the entire length of the field. The geologic structure is comparatively simple, all of the rocks present having a general southwest dip, the inclination varying from  $2^{\circ}$  to  $10^{\circ}$ . Faulting, generally trending nearly at right angles to the strike of the beds, occurs at several localities, the most prominent example of which is about 6 miles south of Bridger, near the center of T. 7 S., R. 23 E., where a depressed block fault, with its longer axis lying across the strike and widening in the direction of the dip, offsets the coal found in the Eagle about three-quarters of a mile to the east. There is another prominent fault about 4 miles north of Bridger that offsets the same coal bed for nearly 2 miles. As a rule, these faults will not interfere seriously with mining operations.

All of the coal found in the Bridger field occurs in the Eagle sandstone. The formation contains three coal beds separated by massive sandstone members about 50 ft. in thickness, only one of the coals being workable at any one point in the field. The south point of workable coal occurs in T. 9 S., R. 24 E., the bed containing 2 ft. 6 in. of coal in two benches, separated by a 6-in. bone parting. To the north, in the Clark Fork valley, in the vicinity of Bridger and Coalville, the coal being worked varies from 4 to 6 ft. in thickness, usually occurring in three benches, separated by shale or bone partings. On Rock creek, near Joliet, the bed being worked is thinner, containing only from 2 ft. to 2 ft. 6 in. of coal, mostly broken into thin benches. The coals of this field are of lower grade than those being mined at Electric and Trail creek, but compare favorably with the Lewistown and Great Falls coals.

*Stillwater Field.*—A small coal field that has remained undescribed up to the present time, and here called the Stillwater field, is located in the valley of the Stillwater river, on the boundary line between Sweetwater and Carbon counties. The field lies about 35 miles northwest of Red Lodge, near the base of the rugged mountains surrounding the Yellowstone National Park. It lies almost wholly within T. 4 S., R. 16 E., and contains about 10 sq. miles of area underlain by workable coal occurring at the same horizon as that mined in the Bridger field.

The Eagle sandstone, the coal-bearing formation in this field, is about 300 ft. thick, and is exposed on either side of the Stillwater valley for several miles along an irregular line of outcrop, with dips

varying from east to northeast and north in direction. The coal present occurs in a carbonaceous shale zone at the top of the Eagle, which, in turn, is overlain by sandy beds occupying the stratigraphic position of the Claggett shale. A single bed of coal is present on this horizon, averaging from 4 to 6 ft. in thickness, but it is much broken by shale and bone partings, the thickest single bed measured being a little over 3 ft. in thickness.

The grade of coal in this field is about identical with that of the Bridger coals, being a fair grade of bituminous. The heating value is only a few units less than that of the Bridger coal, and the chemical analyses give practically the same percentage of ash in each of the coals.

*Electric Field.*<sup>1</sup>—The area of coal-bearing rocks constituting the Electric field lies on the south boundary line of Montana, in Park county, adjacent to the Yellowstone National Park. The field covers about 20 sq. miles, lying in T. 9 S., Rs. 7 and 8 E., along the Yellowstone river and the minor streams leading into it.

The rocks in which the coals of this field are found occur immediately above a mass of dark marine beds easily recognizable as the Colorado shale, and, therefore, occupy a position approximating that of the Eagle, Claggett, and Judith River formations indicated in Fig. 2. Immediately above the Colorado shale is found a thickness of a little over 300 ft. of sandstone that is soft, generally massive, and contains a few shaly layers, and at the top a coal and carbonaceous shale bed 6 ft. in thickness. This agrees very closely with the Eagle sandstone as developed farther east in the Stillwater and Bridger fields. Above this basal sandstone are found a series of alternating sandstones and shales containing two more coal zones, but the stratigraphic equivalents of the Claggett and Judith River formations are not distinguishable.

The structure of the field is complex. Described in a general way, it may be said to represent a fault block narrowing to an apex toward the north and depressed relatively many thousand feet. The block is highly folded and faulted, the faults being of both normal and thrust types, with great irregularity in the angles of dip of the fault planes.

The complexity of the structure is the chief difficulty met with in the mines of this field, for in all the underground workings faults of every type are continually being encountered. On the other hand, the high grade of fuel occurring in this field is almost certainly due to the metamorphism resulting from these structural disturbances. This is especially noticeable in some of the mines where anthracitiza-

tion of the coals is attendant upon sharp folds or occurs in the vicinity of faults.

The coals of this field occur in three beds distributed through about 300 ft. of rocks; the uppermost of these three beds, lying a little more than 200 ft. above the bed next below it, is the only one that has been extensively developed, as it alone is prevailingly coking in character. These coals are easily the highest-grade coals in their class occurring in Montana. Their average heating value on the air-dried basis, 11,800 B.t.u., and their average moisture content, 2.4, are the best values obtained from any true bituminous coals in the State. The coals are coking, practically all of the output being coked and marketed for smelter use at Butte and Anaconda.

*Trail Creek Field*, <sup>6, 12, 45</sup>.—In all of the earlier publications dealing with the coal areas in the vicinity of Trail creek and Livingston the term "Bozeman coal field" is used. When this name was first adopted Bozeman was the principal town in the region, but at present it seems undesirable to continue the use of this name because the coal-bearing rocks are not exposed near Bozeman but are well developed along continuous outcrops in the general vicinity of Trail creek. The field is not a large one, although, because of its proximity to the main line of the Northern Pacific railroad, it was the first coal area to be extensively developed in Montana. The field contains a total area of about 15 sq. miles underlain by workable coal occupying two straight elongated tracts which meet at Chestnut, making a V-shaped outline on the map. The area is partly in Gallatin and partly in Park county and lies midway between Bozeman and Livingston.

The coal-bearing rocks of this field are very similar to those found in the Electric area. Overlying the marine Colorado shale are found from 750 to 900 ft. of sandstones occupying the stratigraphic position of the Eagle sandstone in other parts of Montana and containing several coal beds of commercial importance. Except for the greater thickness, which in a sandstone of its character is not unusual, the rocks agree closely with the Eagle sandstone occurring farther east in the Stillwater and Bridger fields and can be correlated with that formation with considerable certainty. Overlying this coal group is found a thickness of 5,000 ft. or more of rocks predominantly tuffaceous in character, consisting of brown shales and sandstones with intercalated agglomerate largely andesitic throughout, occupying the approximate stratigraphic position of the Claggett, Judith River and Bearpaw formations of other parts of Montana, and being a purely local development in the geologic column of this part of the State.

The structure of the field is complex, both folds and faults being numerous. Along both sides of the valley of Trail creek are found two anticlines bringing up Palæozoic rocks and between them a narrow tract of the coal-bearing Cretaceous formations broken by prominent strike faults.

The coals present occur in several irregular beds that are not productive throughout all of the area mapped. Their variability in character and thickness, together with the complex structures present, makes successful mining in the field very difficult. In grade the coals rank next after those from the Electric field in the class of bituminous coals in Montana, having a slightly lower heating value and considerably greater moisture content than the Electric coals.

Development has continued in this field for many years and it is the only coal area in Montana from which a large part of the easily accessible coal has already been mined.

*Gallatin Field* <sup>27, 32</sup>.—Coal has been known to be present in the group of mountains lying between the West Gallatin river and the Madison river in the southern part of Gallatin and Madison counties, Montana, for over 30 years, but few or no data have been published concerning it. Two areas are definitely known to be coal-bearing, one on the headwaters of Jackass creek north of Lone mountain, and the other on the headwaters of Dodge creek about 10 miles southeast of the mountain mass known as the Sphinx. The country is rugged and inaccessible, the nearest railroad point being more than 30 miles distant, so that the field has remained undeveloped, in spite of the fact that coals approaching anthracite or semi-anthracite in grade and easily the highest class of fuels found in Montana are known to occur there.

The formation containing the coal in this field is probably identical or very similar to the coal-bearing group found in the Electric field, which lies only about 30 miles to the southeast. Colorado shale is known to be present as in the Electric field and above it a considerable thickness of sandy and shale beds containing the coals. In the Dodge Creek area three beds from 4 to 6 ft. thick are known to be present. The main structural feature in each of these coal-bearing areas is a broad open syncline more or less flexed by minor undulations and breaks in the strata. The area on the headwaters of Jackass creek lies adjacent to a large igneous mass of porphyrite many miles in extent and this occurrence probably accounts for the presence of the very high-grade coals reported. A single proximate analysis of coal from the field has been published, giving the following: Moisture, 5.3; volatile matter, 5.6; fixed carbon, 84.7; and

ash, 4.4. This gives a fuel ratio of 15.1, and indicates that the sample analyzed is either anthracite or semi-anthracite coal.

*Lombard Field*<sup>41</sup>.—Coal is known to be present probably in commercial quantities in the vicinity of Lombard in Gallatin and Broadwater counties. The area in which the coal occurs lies between Lombard and Toston and occupies about 6 sq. miles. The Kootenai formation is known to be present here and it probably contains the coal-bearing rocks found in the district. The structure is complex, the strata being much broken, so that some of the coal present which is reported to be coking has been altered to such an extent that it is essentially graphite.

*Great Falls Field*<sup>14, 15, 22, 23</sup>.—The Great Falls field as generally known at present comprises the large coal-bearing area extending east from the Missouri river in the vicinity of Great Falls for a distance of 60 miles along the base of the Little Belt mountains to a point beyond Stanford. It merges into the area of the Lewistown field, from which it is not divided by any sharp natural boundary. The field lies partly in Cascade and partly in Fergus county.

Throughout this field the coal occurs at one horizon about 60 ft. above the base in the Kootenai (Lower Cretaceous) formation. Coal of workable thickness is not contained, however, at all points on this horizon, but varies locally, there being three principal areas containing minable coal in the field. The first and most important of these areas is in the vicinity of Belt and Sand Coulee and contains 230 sq. miles underlain by workable coal, from which by far the greater part of the production of the field has been mined. The second area, containing 38 sq. miles of workable coal, lies in the vicinity of Spion Kop and Geyser, and the third, with 48 sq. miles of workable coal land, is situated near Stanford. The Kootenai formation as developed in this field has a thickness of about 475 ft. and consists mainly of sandstone and sandy shale occurring in alternate succession. It rests conformably on variegated sandy shales and sandstone of Juriassic age and is overlain by the bluish gray shale of the Colorado formation.

The geologic structure of the field is comparatively simple. The rocks dip at small angles to the northeast away from the adjoining mountains. In a narrow zone bordering the Little Belt range the rocks dip from 10° to 15°, but in passing outward under the plains they flatten rapidly, so that in the coal-bearing areas the dips rarely exceed 4°. However, there are many minor rolls and undulations in the strata, most of which are not perceptible to the casual observer. Minor faults are also more or less common throughout the coal area, especially in the vicinity of Belt, where they have been troublesome in mining operations.

In the vicinity of Sand Coulee the one-coal-bearing bed of commercial importance present consists of coal interbedded with layers of bony shale and clay, the coal content ranging from 6 to 14 ft. in thickness in different parts of the district. The arrangement of the coal is in two principal benches, the upper much thicker than the lower. In the vicinity of Belt the coal bed averages about 6 ft. in thickness, occurring in three benches separated by partings of bone. At the Geyser locality the bed averages from 3 to 6 ft., while near Stanford it ranges from 6 to 18 ft., including many partings present.

The coals of the Great Falls field are to be regarded as medium-grade bituminous. They should probably rank the lowest of the true bituminous coals in the State, having lower heating values both on the air-dried basis and on the basis of theoretically pure coal than both the Lewistown and Bridger coals. Their ash content is high, averaging over 18 per cent., and, occurring in conjunction with considerable sulphur in the form of pyrite nodules, renders it necessary to wash these coals before placing them on the market.

*Lewistown Field*,<sup>3, 4, 12</sup>.—The Lewistown coal field as generally known comprises not only the limited district near Lewistown where considerable development has taken place, but also the western extension of that district along the north slopes of the Big Snowy and Little Belt mountains, to where it joins the Great Falls field. It is situated in the center of Montana, including a part of Fergus county and a few square miles in the north part of Meagher county. The greater part of the field lies in the Judith basin, a name applied to the principal drainage area of the Judith river. In all there are about 150 sq. miles of the area in this field that are underlain by workable coals within minable depth.

The rocks encountered in the Lewistown field range in age from Lower Carboniferous to Quaternary, but all of the workable coal in the region occurs at the single horizon found near the base of the Kootenai formation. On the whole, the Kootenai in this field is very similar to that of the Great Falls field except that it is slightly thicker, averaging a little more than 500 ft. The coal horizon, occurring about 90 ft. above the base of the formation, is easily traceable by means of the prominent pebbly and gritty sandstone member about 50 ft. thick, lying immediately above the coal, and generally standing out in bold ridges timbered with pines.

The structure in the western part of the field is relatively simple, the beds present dipping to the north at slight angles away from the Little Belt and Big Snowy mountains. In the eastern part of the field the principal structural features are a large group of laccoliths,

the largest of which form the Judith and Moccasin mountains, while the smaller ones are merely small dome-shaped uplifts not over one mile across and often without topographic expression. Erosion has removed the softer Cretaceous rocks from these uplifts, exposing Palæozoic or igneous formations, and as a result the coal-bearing rocks encircle them, the continuity of the coal outcrop being broken here and there by irregular igneous masses.

As in the Great Falls field to the west, the coals in the Lewistown field are not continuous throughout the area, but are productive only in limited districts with unproductive areas between them. The most important of these districts are: (1) the Buffalo Creek district, on the north slope of the Little Belt mountains; (2) the Rock Creek district, on the north slope of the Big Snowy mountains; (3) the Lewistown district, on Big Spring creek just above Lewistown; and (4) the Macdonald Creek district, the largest of all of these, lying on the east edge of the field south of the Judith mountains.

The coals where mined at present vary from 2.5 to 8 ft. in thickness, and, as in the Great Falls field, are usually broken by partings of clay and bone. The coal is a medium-grade bituminous in character and very similar to the Great Falls coal except that it is rather more free from impurities, the ash content averaging almost 10 per cent. lower than the Great Falls coals. It is persistently banded in appearance, with alternating layers of bright and dull coal. The sulphur content is relatively high, averaging over 4 per cent.

*Valier Field.*—A small heretofore undescribed coal field occupies a small area near the town of Valier in Teton county in the north-west part of the State. The field includes about 6 square miles of area that is underlain by workable coal, and although comparatively small is of considerable local importance because of the scarcity of coal in that region,

The coal occurs in a single workable bed at the top of the Eagle sandstone, which is typically developed here, and therefore occupies the same stratigraphic position as the coal mined in the Bridger, Stillwater, and possibly Electric and Trail Creek fields in the southern part of the State. The structure is very simple, the rocks lying so nearly flat and undisturbed that the slight westward inclination of the strata is barely perceptible.

The single coal bed present is thin, rarely being more than 30 in. in thickness, and averaging only about 2 ft. The coal, however, is of good quality, comparing favorably with that mined from the Bridger field and being of slightly better quality than the coal from



the Lewistown field. The ash content is lower and the heating value decidedly higher than that of the coals from the Great Falls field.

*Blackfoot Field.*—The Blackfoot field is another area that has remained undescribed up to the present time. It lies within 15 miles of the international boundary in the northwest part of Teton county and should develop into considerable importance as a local source of fuel. The field occupies a long narrow area extending in a northwest-southeast direction for about 15 miles across the upper branches of the south fork of the Milk river and is practically undeveloped.

The coal present lies at a single horizon occurring at the top of a sandstone formation locally known as the Horsethief sandstone, lying immediately above the Bearpaw shale, which is the same in stratigraphic position as that occupied by the Lennep sandstone found in the upper part of the Musselshell valley north of the Crazy mountains. The structure of the field is very complex, for it lies in a belt of folded and faulted rocks lying at the base of the Rocky mountains. The faults are mostly of the overthrust type. This complexity of structure will make any extensive mining operations very difficult to carry out, but on the other hand the dynamic disturbances have served to alter the coal into a relatively high-grade fuel. The thickest coal found measures 3.5 ft. in thickness, but the average thickness of the workable coal is not over 2.5 ft.

The coal is of excellent quality; the heating value of the theoretically pure coal is 13,890 B.t.u., and considered on this basis it ranks with the better grade bituminous coals of Montana, being slightly above the Bridger coal in grade.

#### *Fields Containing Sub-Bituminous Coal.*

*Bull Mountain Field,* <sup>12, 21, 37, 54.</sup>—The Bull Mountain field is located in the central part of Montana, practically all of it lying in the northern part of Yellowstone county except for a few small areas that lie north of the Musselshell river in Fergus county. Its length from north to south is nearly 25 miles and from east to west 35 to 40 miles. Its total area is about 750 sq. miles, practically all of which is land underlain by workable coal. An earlier statement assigns a total of about 55 sq. miles of coal-bearing area to this field.

Nearly all of the workable coals found occur in the Fort Union formation. It forms the uppermost group of rocks exposed in the field and consists of a thickness of 1,650 ft. of yellowish sandstone and shales interstratified with coal beds. It is prolifically coal-bearing, containing at least 20 beds attaining a thickness of more than 2 ft. of coal. The beds are most numerous in the upper part of the

formation, where they occur at intervals of 50 ft. or less, while in the lower part the intervals are 100 ft. or more.

The geologic structure of the field is simple, the rocks lying practically flat for the most part. The slight dips present form a shallow synclinal basin in the central part of the field, having a general northwest axial trend and a rather accentuated dip at its northwestern extremity. The syncline merges on its northern border into an anticline whose flanks dip about  $5^{\circ}$ , while this anticline is paralleled on the north by a smaller but sharper syncline. The rocks are practically undisturbed even by minor faults, which with the slight dips present makes the structural conditions ideal for mining.

The coal of this field is a high-grade sub-bituminous very nearly approaching the grade of true bituminous coal. Its rather poor stocking quality is the chief factor that prevents it from being classed as a bituminous coal. It is pitch black to brownish black in color and has a dark brown to black streak. It shows lustrous bands alternating with coal of a dull satiny luster, containing mineral charcoal or "mother" coal.

The average heating value of this fuel on an air-dried basis is greater than that of both the Bridger and Great Falls coals and is about the same as that of the Lewistown and Red Lodge coals, but on the basis of theoretically pure coal the heating value is lower than any of these, except the Red Lodge coal. The Bull Mountain coals with those from Red Lodge should rank first among the sub-bituminous coals found in Montana.

*Red Lodge Field*, <sup>11, 51, 53</sup>.—The Red Lodge field was formerly called the Rocky Ford field, but is now better known by the designation given above from the town of Red Lodge, which was the place of original development and still continues to be the chief mining center. It is situated at the foot of the Beartooth mountains in Carbon county, between the Yellowstone river and the Clark fork, one of the tributaries of the Yellowstone. The field extends for a distance of 8 miles from north to south and an equal distance from east to west. About one-half of this area of 32 sq. miles is underlain by workable coal.

The rocks outcropping in this field belong almost entirely to the Fort Union formation. The sandstones and shales of this formation comprise a mass of rocks 8,500 ft. in thickness in which carbonaceous shale and coal beds are interpolated in various horizons. Workable coals, however, do not occur throughout this immense thickness of rocks, but are confined to a productive member 825 ft. thick, lying between a lower barren member 5,700 ft. thick and an upper barren

member about 2,000 ft. thick. The sandstone and shale of the productive member of the formation closely resemble the rocks from the barren portions and do not seem to indicate any essential difference in the conditions of deposition, the carbonaceous shales and the workable coals present alone serving to distinguish the member. A section of the coal-bearing portion of the rocks present in the field as exposed on the east side of Rock creek near Red Lodge gave a total of 81 ft. of coal distributed in 15 beds in a total thickness of 800 ft. of rocks. This very large amount of coal gives a fair idea of the prolific coal-bearing character of the Fort Union formation.

A peculiar feature of this field is the presence of a number of dikes of camptonite cutting through the sedimentary rocks and forming low, dark-colored ridges extending in a northwest-southeast direction across the field. They have had little or no metamorphic effect upon the surrounding rocks and where they have cut the coal beds little or no anthracitization has taken place, nothing but charred coal being found.

Structurally, the rocks form a part of an eroded monocline dipping southwestward, which is abruptly terminated at the base of the Bear-tooth range by a fault having a throw of several thousand feet, bringing Carboniferous limestones in contact with the Fort Union rocks. The southwestward dip of the beds is variable, being  $18^{\circ}$  at Red Lodge, but gradually flattening going southwestward until they are nearly horizontal near the south limit of the field, there being many minor undulations in the strata in this distance. The Bridger field lying only 12 miles to the northeast occupies the same southwestward dipping monocline present in the Red Lodge field, the only difference being that the coals at Bridger lie at a horizon very much lower than those at Red Lodge.

The coals present were apparently deposited in basins believed to have been shallower toward the southwest because all of the coals thin in that direction and merge into carbonaceous shale, but on the whole the beds present are very persistent and are not to be classed as lenticular deposits. The coals have a black-colored, pitchy luster and well developed, though irregular, joints. They are medium in hardness and relatively free from injurious impurities. They are about as bright in appearance as some of the bituminous coals of Pennsylvania, and, unlike some of the sub-bituminous coal, do not lose their luster when exposed to the air for a short time. In heating value these coals excel the bituminous coals from the Bridger and Great Falls fields, but their poor stocking qualities and heating value on the basis of theoretically pure coal place them in the sub-bituminous class.

At the present time this field is entering a period of extensive development which promises a continued and steady production for many years.

*Missoula and Drummond Fields.*—These two fields are isolated areas lying in the mountainous part of western Montana in Missoula and Granite counties. They are the only two areas which up to this time have produced coal in commercial quantities out of the large number of isolated fields containing coal in the Tertiary lake beds in this part of the State.

The coal occurs in the part of the Tertiary lake beds that is approximately White River in age, being found in the lower 100 ft. of the rocks, which are mainly massive tuffs composed in part of clay. The coals are apt to be lenticular, showing considerable variability in thickness. Natural exposures are scarce because the coal crumbles rapidly in weathering. It is distinctly banded, showing alternate layers of dull to bright black coal, and has a conchoidal fracture, occasionally showing a tough woody structure. The coal is distinctly sub-bituminous in grade, and some of it approaches a true lignite.

*Milk River Field,* <sup>25</sup>.—The Milk River field occupies a large portion of Chouteau county in north-central Montana, and practically all of it lies in the drainage basin of Milk river. By no means all of the large area included in this field is underlain by workable coal, but the districts containing minable fuel are so numerous and so widely scattered over the entire field that it is best treated as a single large coal field.

The formations found in the Milk River field are almost identical with those found farther south in central Montana along the Missoula and Musselshell River valleys, which may be spoken of as the standard section of the Cretaceous rocks for Montana. The Eagle sandstone, Claggett formation, Judith River formation, and Bearpaw shale are present and present little variation from their development to the south.

All of the coals of workable thickness in this field occur within 150 ft. of the top of the Judith River formation. They are lenticular in shape and show variable thicknesses up to a total of 9 ft. of coal on a single outcrop. The beds are noticeably thinner and of poorer grade in the eastern part of the field. Generally, there is only one bed at a single locality of workable thickness, but in a few places as many as four beds are found.

All of these coals may be classed as a fair grade of sub-bituminous. They are pitch black to brownish black in color and have a brown streak, their luster being bright and waxy. Chemical analyses show

that they are comparatively low in sulphur and high in moisture and ash. The heating value of these coals, taken on the basis of a theoretically pure coal, averages only 12,350 B.t.u., which is the lowest value obtained for any of the sub-bituminous coals in Montana, although on the basis of the air-dried sample the heating value exceeds that of the coal from the Missoula and Drummond fields.

*The Eastern Plains Region of Lignite and Sub-Bituminous Coal,*

1, 2, 5, 16, 17, 40.

This very large coal and lignite bearing area covers nearly all of the east one-half of Montana, including practically all of Valley, Dawson, Custer and Rosebud counties within its boundaries. It is estimated to contain 365 of the total 380 billion short tons of lignite and coal found in Montana. About 40 per cent. of this total tonnage is estimated to consist of sub-bituminous coal, while the remainder is a true lignite. Its total tonnage and area greatly exceed that of all the other fields in the State taken together, but up to the present time it has furnished almost nothing to the annual production of coal in the State.

All but a very small proportion of the coal in this region occurs in the Fort Union formation, which here has its typical development. The number and distribution of the coals present are about equal or slightly exceed the number of beds and the amount of coal found in the Bull Mountain field, which can properly be regarded as an outlier of the great eastern area which has been isolated by erosion since the beds were first deposited. The structure over all of the area is very simple, the rocks for the most part lying practically horizontal or else flexed into very broad gentle undulations that are barely perceptible on casual examination. The only exception to this is an anticline whose axis, trending in a northwest-southeast direction almost exactly paralleled by that of the Black Hills and Bighorn uplifts, passes through a point a few miles southwest of Glendive in Dawson county and extends for over 60 miles to the southeast, to the North Dakota boundary. This fold is asymmetric, the steeper-dipping limb lying on the southwest side, where the beds are inclined at angles varying from 10° to 30° but flatten very rapidly in traveling away from the fold toward the southwest.

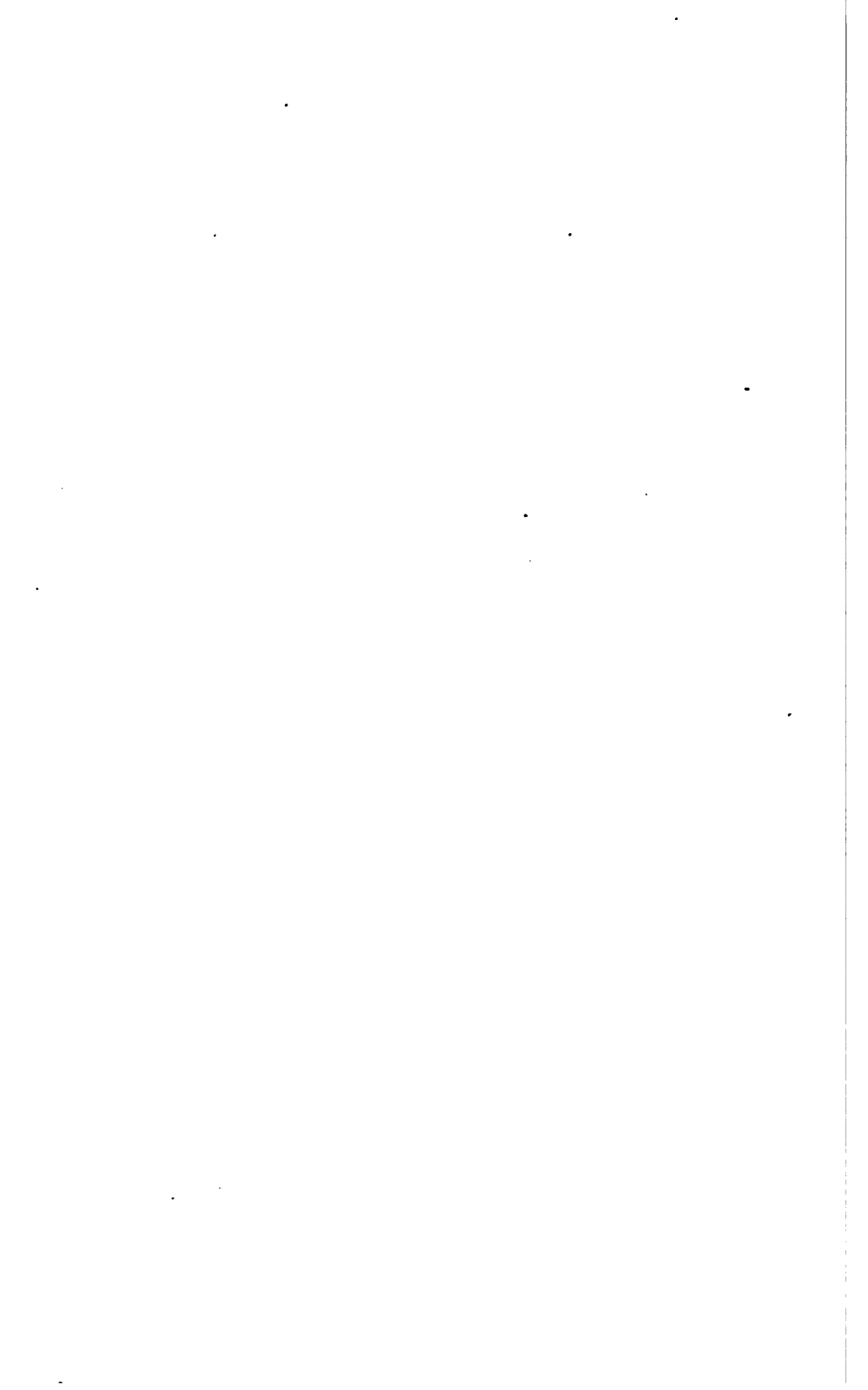
The fuel in the eastern one-half of this region is a true lignite and constitutes the lowest grade of fuel found in Montana. Its heating value for the theoretically pure coal, ash and moisture free, averages 11,820 B.t.u., while on the air-dried basis the result is 8,505 B.t.u. Both of these figures are the lowest obtained for any of the coaly fuels found in Montana. In general, the lignite is brown, lusterless

and woody, showing the grain of the wood and frequently the outlines of entire tree trunks from which all or a large part of the material was formed. Going toward the west across this region the lignite changes gradually into a black, shiny, sub-bituminous coal. The change is so gradual that probably no two observers would agree as to the place where the line of division should be drawn. As the brown color disappears the lignite loses more and more of its woody character. Near Glendive it is black but lusterless, at Miles City its color is a little more pronounced, and much of it is black and shiny, while on the extreme western edge of the area it has practically lost all traces of its woody structure and has obtained a brilliant luster throughout, being a true sub-bituminous coal.

### *Literature.*

1. Beekly, A. L.—The Culbertson Lignite Field, Montana: *U. S. Geol. Survey Bull.*, 471, 1912.
2. Bowen, C. F.—The Baker Lignite Field, Montana: *U. S. Geol. Survey Bull.*, 471, 1912.
3. Calvert, W. R.—The Lewistown Coal Field, Montana: *U. S. Geol. Survey Bull.*, 341, 1909.
4. ——— Geology of the Lewistown Coal Field, Montana: *U. S. Geol. Survey Bull.*, 390, 1909.
5. ——— Geology of Certain Lignite Fields in Eastern Montana. *U. S. Geol. Survey Bull.*, 471, 1912.
6. ——— The Livingston and Trail Creek Coal Fields, Montana: *U. S. Geol. Survey Bull.*, 471, 1912.
7. ——— The Electric Coal Field, Montana: *U. S. Geol. Survey Bull.*, 471, 1912.
8. Collier, A. J., and Smith, C. D.—The Miles City Coal Field, Montana: *U. S. Geol. Survey Bull.*, 341, 1909.
9. Conrad, T. W.—Observations on the Eocene Lignite Formation of the United States: *Phil. Acad. Sci. Proc.*, vol. 17, 1865.
10. Davis, W. M.—Relation of the Coal of Montana to the Older Rocks: *10th Census U. S.*, vol. 15, 1886.
11. Darton, N. H.—Coals of Carbon County, Montana: *U. S. Geol. Survey Bull.*, 316, 1907.
12. Eldridge, G. H.—Montana Coal Fields; *10th Census U. S.*, vol. 15, 1886.
13. Fisher, C. A.—Development of the Bear Creek Coal Fields, Montana: *U. S. Geol. Survey Bull.*, 285, 1906.
14. ——— The Great Falls Coal Field, Montana: *U. S. Geol. Survey Bull.*, 316, 1907.
15. ——— Geology of the Great Falls Coal Field, Montana: *U. S. Geol. Survey Bull.*, 356, 1909.
16. Hance, J. H.—The Glendive Lignite Field, Montana: *U. S. Geol. Survey Bull.*, 471, 1912.
17. Herald F. A.—The Terry Lignite Field, Montana: *U. S. Geol. Survey Bull.*, 471, 1912.
18. Knowlton, F. H.—List of Fossil Plants of the Bozeman, Montana, Coal Field: *U. S. Geol. Survey Bull.*, 105, 1893.
19. Leonard, A. G.—The North Dakota-Montana Lignite Area: *U. S. Geol. Survey Bull.*, 285, 1906.
20. Leonard, A. G., and Smith, C. D.—The Sentinel Butte Lignite Field, North Dakota and Montana: *U. S. Geol. Survey Bull.*, 341, 1909.
21. Lupton, C. T.—The Eastern Part of the Bull Mountain Coal Field, Montana: *U. S. Geol. Survey Bull.*, 431, 1911.

22. Newberry, J. S.—The Great Falls Coal Field, Montana: *School of Mines Quart.*, vol. 8, 1887.
23. ——— The Flora of the Great Falls Coal Field, Montana: *Am. Jour. Sci.*, 3d ser., vol. 41, 1891.
24. Parsons, F. W.—Montana's Great Coal Fields and Its Collieries: *Eng. and Min. Jour.*, vol. 84, 1907.
25. Pepperberg, L. J.—The Milk River Coal Field, Montana: *U. S. Geol. Survey Bull.*, 381, 1909.
26. ——— The Southern Extension of the Milk River Coal Field, *U. S. Geol. Survey Bull.*, 471, 1912.
27. Peale, A. C.—Three Forks Folio, Montana: *Geol. Atlas U. S.*, Folio 24, *U. S. Geol. Survey*, 1896.
28. Ritter, E. A.—Les basins lignitiferes et houillers des Montagnes Rocheuses: *Annales des Mines*, 10<sup>e</sup> Ser. t. 10, livr. 7, 1906.
29. Rogers, H. D.—The Lignite Deposits of the Upper Missouri: *Boston Soc. Nat. Hist. Proc.*, vol. 5, 1856.
30. Rowe, J. P.—Some Montana Coal Fields: *Am. Geol.*, vol. 32, 1903.
31. ——— Montana Coal Fields: *Mg. Mag.*, vol. 11, 1905.
32. ——— Montana Coal and Lignite Deposits: *Mont. Univ. Bull.*, 37, 1906.
33. ——— Montana Coal and Lignite Deposits: *Min. World*, vol. 28, 1907.
34. ——— Some Economic Geology of Montana: *Mont. Univ. Bull.*, 50, 1908.
35. ——— Coal and Lignite Deposits of Montana: *Min. World*, vol. 28, 1908.
36. ——— Red Lodge and Bear Creek Coal Mines: *Min. World*, vol. 32, 1910.
37. Richards, R. W.—The Central Part of the Bull Mountain Coal Field, Montana: *U. S. Geol. Survey Bull.*, 381, 1909.
38. Shurick, A. T.—The Great Falls Coal Field, Montana: *Eng. and Min. Jour.*, vol. 87, 1909.
39. Smith, C. D.—The Fort Peck Lignite Field, Montana: *U. S. Geol. Survey Bull.*, 381, 1909.
40. Stebinger, Eugene.—The Sidney Lignite Field, Montana: *U. S. Geol. Survey Bull.*, 471, 1912.
41. Storrs, L. S.—The Rocky Mountain Coal Fields: *22d Annual Report, U. S. Geol. Survey*, Pt. III, 1902.
42. Stone, R. W.—Coal near the Crazy Mountains, Montana: *U. S. Geol. Survey Bull.*, 341, 1909.
43. Tarr, R. P.—The Montana Coal Situation: *Eng. and Min. Jour.*, vol. 84, 1907.
44. Washburne, C. W.—Coal Fields of the Northeast Side of the Bighorn Basin, Wyoming, and of Bridger, Montana: *U. S. Geol. Survey Bull.*, 341, 1909.
45. Weed, W. H.—The Cinnabar and Bozeman Coal Fields of Montana: *Geol. Soc. Am.*, vol. 2, 1891.
46. ——— Notes on the Coal Fields of Montana: *School of Mines Quart.*, vol. 12, 1891.
47. ——— Two Montana Coal Fields: *Geol. Soc. Am. Bull.*, vol. 3, 1892.
48. ——— The Coal Fields of Montana, *Eng. and Min. Jour.*, vol. 53, 1892; also vol. 55, 1893.
49. ——— Montana Coal Fields: *16th Annual Report, U. S. Geol. Survey*, Pt. IV., 1895.
50. Wegemann, C. H.—Notes on the Coals of the Custer National Forest, Montana: *U. S. Geol. Survey Bull.*, 381, 1909.
51. Wolff, J. E.—Rock Creek and Gardiner River Coal Fields, Montana: *10th Census U. S.*, vol. 15, 1888.
52. Wood, Herbert—Flathead Coal Basin, Montana: *Eng. and Min. Jour.*, vol. 54, 1892.
53. Woodruff, E. G.—The Red Lodge Coal Field, Montana: *U. S. Geol. Survey Bull.*, 341, 1909.
54. Woolsey, L. H.—The Bull Mountain Coal Field, Montana: *U. S. Geol. Survey Bull.*, 341, 1909.





DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1913, when Vol. XLVI. of the *Transactions* will go to press. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## Over-Oxidation of Steel.

BY W. R. SHIMER AND F. O. KICHLIN,\* EASTON, PA.

(New York Meeting, October, 1913.)

THE investigation herein described was carried out for the purpose of studying, both by chemical and metallographical means, the extent of over-oxidation of steel that can be accomplished by excessive over-blowing in a Bessemer converter. In addition there are appended some results of basic open hearth and crucible steels.

### *Remarks on Chemical Methods.*

The test block used was hemispherical in shape, 4.5 in. in diameter and 2 in. thick. Drillings for analysis were obtained by drilling through the entire solid part of the block, carefully avoiding all cracks and blow-holes and mixing these drillings thoroughly. Drillings were carefully examined for scale and the finest were gone over with a microscope to be sure all scale from whatever source had been removed.

Oxygen was determined by the well-known method of Ledebur, modified according to Cushman,<sup>1</sup> with, however, the removal of the preheating tube, which was found unnecessary. This method has been found to give concordant results. Blanks run from 0.0003 to 0.0006 g. Duplicate determinations varied not more than 0.001 to 0.003 per cent.

It seems to be generally supposed that the hydrogen method gives only that oxygen which is combined with iron. Whether this be true or not, the content of oxygen existing as iron oxide no doubt predominates sufficiently, so that the result obtained is sufficient to indicate whether the steel is over-oxidized or not.

We are well aware that the oxides of manganese and chromium, when existing alone, are not reduced by hydrogen at a red heat. To learn of their action in steel the following work was carried out: A sample of ferro-manganese and of ferro-chrome were each exposed

\* Non-member.

<sup>1</sup> *Journal Industrial and Engineering Chemistry*, vol. iii., p. 372.

in the electric furnace to an atmosphere of oxygen until completely oxidized. These powdered oxides were then run for oxygen by the usual hydrogen method, but only a very small percentage of the total oxygen was obtained in either case.

A sample of rail steel of the following composition was oxidized in the electric furnace as before: C, 0.740 per cent.; Mn, 0.82 per cent.; P, 0.024 per cent.; S, 0.042 per cent.; Si, 0.098 per cent. One-half gram of these completely oxidized drillings were run for oxygen by the hydrogen method. The percentage of oxygen found was slightly higher than the theoretical amount. These reduced drillings were then run for oxides by the iron-iodide method. A residue of less than 0.10 per cent. iron was obtained, carrying with it only traces of manganese.

With the same object in view a sample of drillings from a nickel-chrome steel of approximately the following composition was oxidized as before: C, 0.35 per cent.; Mn, 0.38 per cent.; P, 0.026 per cent.; S, 0.028 per cent.; Si, 0.058 per cent.; Ni, 3.85 per cent.; Cr, 1.95 per cent. The oxidized drillings were then transferred to the apparatus for determining oxygen and run as before. To insure thorough reduction, the drillings were run for oxygen the second time. A slight increase in weight was obtained. A third run gave no further reaction for oxygen. The percentage of oxygen found was again greater than the theoretical figure. The drillings were then dissolved in iron iodide. A slight residue only was obtained, containing merely traces of Fe, Mn, and Cr.

The foregoing experiments tend to show that when manganese and chromium are oxidized, while alloyed with iron, their oxides are readily reduced by hydrogen. This can at least be true when they exist in such amounts as they are usually found in steel.

On this point we might quote from a valuable paper by G. Mars,<sup>2</sup> in which he says: "The oxides of both metals [meaning iron and manganese] are distinguished from each other in this way; when manganese oxide appears alone it will not be reduced by hydrogen, but if both oxides are present then the hydrogen will reduce them." A few of the results for oxygen by the hydrogen method were checked by the iron-iodide method and agreed closely.

The experiments were carried on in a Bessemer converter blowing steel for the Duplex process. Hot metal used, with the exception of Heat I, had the following composition: C, 3.50 per cent.; Mn, 0.70 per cent.; P, 0.450 per cent.; S, 0.050 per cent.; Si, 1.20 per cent.

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<sup>2</sup> Die Bestimmung der Schlackeneinschlüsse im Stahl, *Stahl und Eisen*.

*Experiments.*

*Heat A*:—45,000 lb. of iron were blown in the usual way for soft steel, the converter was turned over and Test 1 taken, which analyzed as follows: C, 0.06 per cent.; Mn, 0.02 per cent.; O, 0.027 and 0.026 per cent.

The vessel was then turned up and the heat blown until the flame showed extensive over-oxidation and the metal was getting cold. It was then turned down and Test 2 taken immediately.

Test 2 analyzed: C, 0.03 per cent.; Mn, 0.01 per cent.; O, 0.074 per cent.

The oxygen content is not as high as might have been expected in a steel, after making such a vigorous attempt at over-oxidation, and when we consider that the test was poured while the steel still contained the full amount of entangled oxides and chilled before they could separate out.

To the metal in the vessel after taking test sample No. 2 was added 3,000 lb. of hot metal. To insure thorough mixing the vessel was manipulated and just a puff of air blown through. It was then turned down and allowed to rest about one minute, and Test 3 was taken while pouring into the ladle.

Test 3 analyzed: C, 0.15 per cent.; Mn, 0.03 per cent.; O, 0.023 per cent.

This test showed how quickly the over-oxidized, or over-blown, heat was deoxidized by the addition of the hot metal.

No microscopic samples were taken of *Heat A*.

*Heat B*:—Since Test 1 (*Heat A*) was blown very low in carbon, *Heat B* was blown to leave more carbon in the bath, and Test 4 taken. *Heat B* weighed 40,000 lb.

Test 4 analyzed: C, 0.25 per cent.; Mn, 0.04 per cent.; O, 0.027 per cent.

The vessel was turned up and blown to apparent over-oxidation, when Test 5 was taken in the usual way.

Test 5 analyzed: C, 0.04 per cent.; Mn, 0.02 per cent.; O, 0.032 per cent.

This heat was recarburized with 9,000 lb. of hot metal, the vessel was manipulated to insure thorough mixing, and Test 6 taken while pouring into the ladle, after allowing a few minutes for the reducing action of the metalloids to be exerted. The analysis of Test 6 showed: C, 0.780 per cent.; Mn, 0.13 per cent.; O, 0.024 per cent.; Si, 0.140 per cent.

See micrographs Nos. 4, 4a, 5, 5a, 6, 6a, on Plate I. Micrographs 4, 5, and 6 (taken before etching specimens) represent Tests

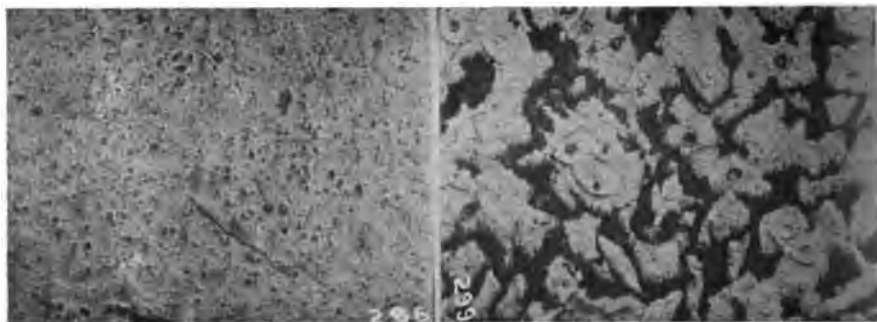


Fig. 4.—Unetched.

Fig. 4a.—Etched.

C, 0.25 per cent. ; O, 0.027 per cent.



Fig. 5.—Unetched.

Fig. 5a.—Etched.

C, 0.04 per cent. ; O, 0.032 per cent..

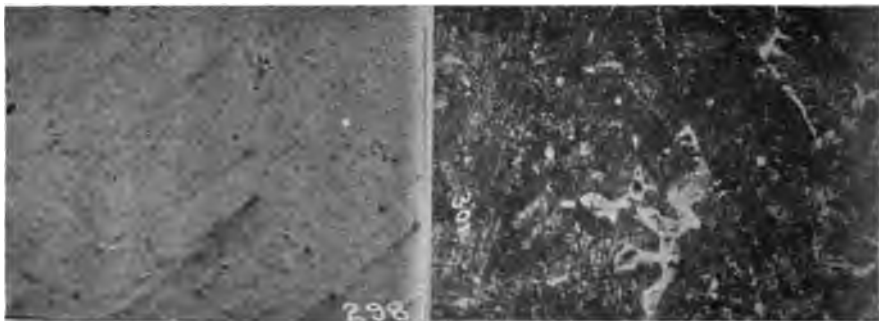


Fig. 6.—Unetched.

Fig. 6a.—Etched.

C, 0.780 per cent. ; O, 0.024 per cent.

PLATE I.—SAMPLES FROM HEAT B. ALL SECTIONS MAGNIFIED 140 DIAMETERS.

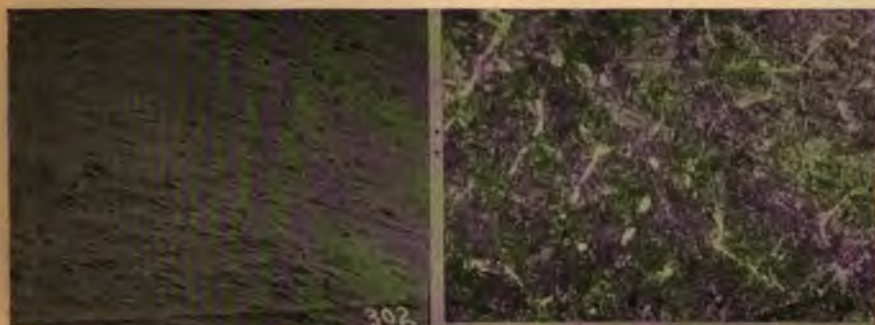


Fig. 7.—Unetched.

Fig. 7a.—Etched.

C, 0.744 per cent. ; O, 0.036 per cent.

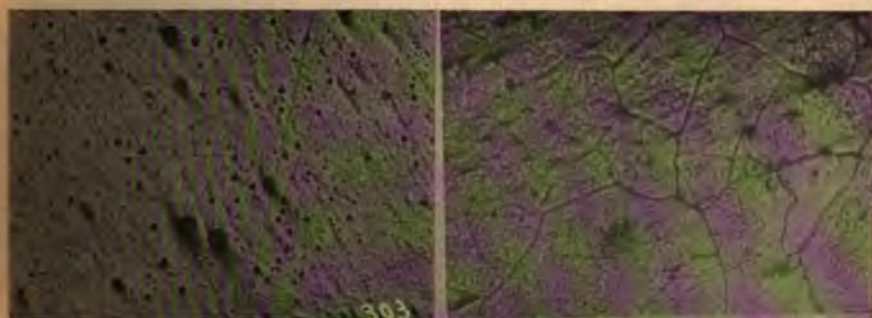


Fig. 8.—Unetched.

Fig. 8a.—Etched.

C, 0.03 per cent. ; O, 0.064 per cent.

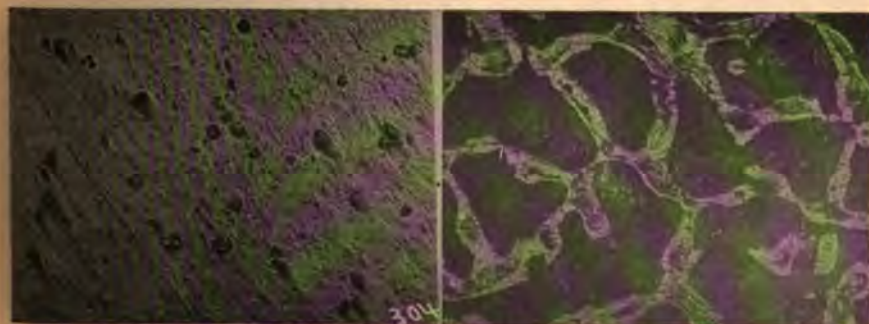


Fig. 9.—Unetched.

Fig. 9a.—Etched.

C, 0.430 per cent. ; O, 0.029 per cent.

4, 5 and 6 and show substantially the same proportion of impurities as the chemical results for oxygen. Nos. 4 and 6 contain fewer pits than No. 5. Also, note in 5a (sample after etching) that the oxides occur in the boundaries of the ferrite crystals. This structure is almost pure ferrite, since there is practically no carbon in this sample.

In the above experiment we were unable to over-blow to any great extent on account of the hot metal being too low in silicon. We therefore awaited an opportunity when the iron was "hot" (*i. e.*, high in silicon), so we could give a long over-blow (say 5 min.) without danger. This would give a very hot blown metal and allow satisfactory conditions for over-oxidation.

*Heat C:* 45,000 lb. were blown and Test 7 taken, which analyzed: C, 0.744 per cent.; Mn, 0.05 per cent.; O, 0.036 per cent. The heat was then blown soft (to about 0.10 per cent. carbon) and then, since the metal was very hot, a prolonged after-blow of about five minutes was given. The vessel was turned down and Test 8 was taken, which analyzed: C, 0.03 per cent.; Mn, 0.01 per cent.; O, 0.064 per cent.

To the vessel was added 5,600 lb. of hot metal for recarburization and after holding for two minutes, the heat was poured and Test 9 was taken. The analysis of Test 9 showed: C, 0.430 per cent.; Mn, 0.02 per cent.; O, 0.029 per cent.

It will be noticed how quickly the addition of the hot metal de-oxidized the bath.

See Plate II., which shows micrographs 7, 8 and 9 (unetched) and 7a, 8a and 9a (etched). No. 7 contains fewer and also smaller pits (or oxide spots) than No. 8, and, in No. 9, the spots are of a different nature; not oxide pits, since they contain bright centers. (These are probably iron phosphide, out of solution, as there was about 0.480 per cent. phosphorus in the blown metal, and this was thrown out of solution when the recarburizer was added.) It will be noticed in the etched micrograph 9a that the ferrite bands contain a peculiar gray center, not found in ordinary steels, which is phosphide of iron, or steadite.

The three tests, Nos. 7, 8 and 9, were forged with the following results:

No. 7 fell to pieces under the first blow of the hammer.

No. 8 forged readily to a 0.75 in. square bar.

No. 9 fell to pieces in the same manner as No. 7.

Nos. 7 and 9 (both high in carbon) contained phosphide of iron, out of solution, which caused them to break during forging.

Micrograph 8f (Plate III.) shows the structure of No. 8 sample after forging. The large dark gray portion is a blow-hole forged together.

*Heat D:* A heat of 42,340 lb. was blown soft immediately after Heat C, and Test 10 was taken. The analysis of Test 10 gave: C, 0.08 per cent.; Mn, 0.02 per cent.; O, 0.027 per cent.

Then the vessel was turned up and the heat given a five-minute after-blow and Test 11 taken. Test 11 analyzed: C, 0.02 per cent.; Mn, 0.02 per cent.; O, 0.048 and 0.049 per cent.

Then 7,620 lb. of hot metal were added to the vessel, which was manipulated to mix the bath, and Test 12 was taken immediately, the analysis being: C, 0.648 per cent.; O, 0.030 per cent.

The heat was then held three minutes and poured out; Test 13 was taken while pouring into the ladle. The analysis of this test showed: C, 0.610 per cent.; O, 0.023 per cent.

See micrographs Nos. 10 to 13 and 10a to 13a and 13a<sub>1</sub>, Plates III. and IV.

No. 10 shows less oxides than No. 11.

No. 11.—Some parts of the sample were better and some worse than the part photographed.

No. 12.—This piece shows less oxides than No. 11.

No. 13 shows lower oxides than No. 12. The large spots shown in the print are slag inclusions.

The etched pieces are shown by micrographs 10a to 13a and 13a<sub>1</sub>. They show the representative structures of the different tests. Nos. 10a and 11a, not having much carbon, show almost pure ferrite. In 11a the oxide spots occur along the boundary lines of the crystals.

Nos. 12a, 13a and 13a<sub>1</sub> show the tests containing the higher carbon (after recarburization), which has thrown the iron phosphide out of solution. The ferrite in these prints contains dark centers; these are the iron phosphide. This explains the nature of the peculiar spots in the unetched tests, Nos. 12 and 13, which are not of the same appearance as oxides. Micrographs 10f and 11f (Plate IV.) show the appearance of the respective tests after forging. The gray spots are forged-out blow-holes. Note the absence of pearlite in these tests.

Test blocks Nos. 12 and 13 would not forge; they both fell to pieces on account of their iron phosphide content.

*Heat E.*—To 48,340 lb. of hot metal, 2,000 lb. of magnetic ore was added, before blowing, with the object of reducing the time of the blow and of studying the extent to which the steel might be over-oxidized. Test 14 was taken immediately after the blow. Test

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NOTE.—Micrographs marked *f* represent the structures of forged tests, after etching.



Fig. 8f.—Structure after forging and etching.  
O, 0.064 per cent.

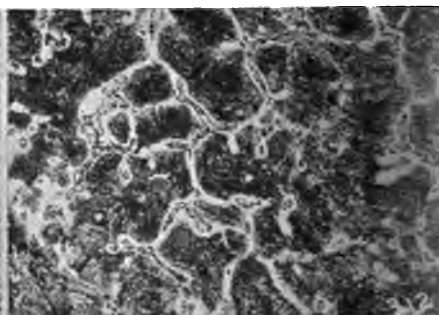


Fig. 13a<sub>1</sub>.—Etched.

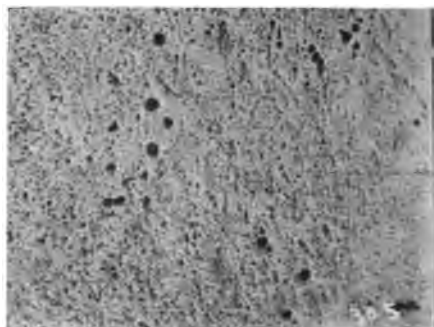


Fig. 10.—Unetched.

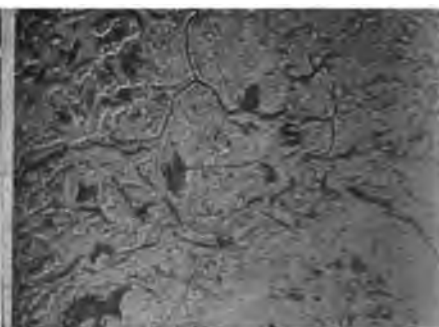


Fig. 10a.—Etched.

C, 0.08 per cent. ; O, 0.027 per cent.

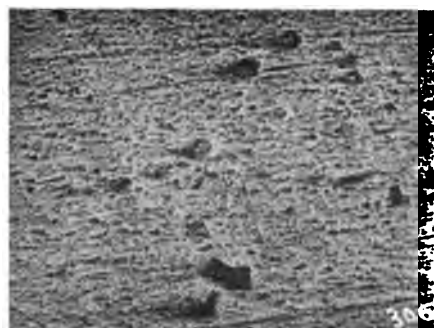


Fig. 11.—Unetched.



Fig. 11a.—Etched.

C, 0.02 per cent. ; O, 0.048, 0.049 per cent.

PLATE III.—ALL SECTIONS MAGNIFIED 140 DIAMETERS.





Fig. 12.—Unetched.



Fig. 12a.—Etched.

C, 0.648 per cent. ; O, 0.030 per cent.



Fig. 13.—Unetched.



Fig. 13a.—Etched.

C, 0.610 per cent. ; O, 0.023 per cent.



Fig. 10f.—Sample 10 forged and etched.

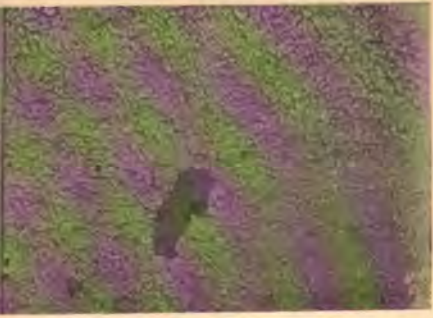


Fig. 11f.—Sample 11 forged and etched.

PLATE IV.—ALL SECTIONS MAGNIFIED 140 DIAMETERS.

14 analyzed: C, 0.08 per cent.; O, 0.024 per cent. The blow just previous to this one (Heat D) and the one following (Heat F) each took 14 minutes to blow soft, while this heat, E, took only 12 minutes, a reduction of two minutes. From the oxygen content we see that the steel was not over-oxidized. No microscopic samples were taken of Heat E.

*Heat F*:—50,440 lb. of metal were blown to 0.25 per cent. carbon and 1,000 lb. of magnetic ore was added to the ladle. A violent reaction took place in the ladle. The ladle was taken to the open hearth and Test 15 taken while pouring into the furnace. The time from filling the ladle to catching the test was 30 minutes, thus giving the ore time to act and the bath to clear. The analysis of Test 15 gave: C, 0.13 per cent.; O, 0.017 per cent.

It is interesting to note how low the content of oxygen is in this steel, 30 minutes after the ore addition to ladle. No microscopic samples were taken of Heat F.

*Heat G*:—We then blew a heat dead soft before adding ore and, further, added ore to the vessel, in order better to take care of the reaction, or boiling over. To carry out this experiment, 48,000 lb. of metal were blown soft and Test 16 taken, which analyzed: C, 0.08 per cent.; O, 0.024 per cent.

While the vessel was resting on its side, 1,000 lb. of ore were added and five minutes allowed for the reaction to take place. A large piece of mixer scull (about 5,000 lb.) remained in the vessel from a previous heat and was partly melted away by the bath while holding the metal in the vessel for the action of the ore. Test No. 17 was then taken. Test 17 gave the following analysis: C, 0.14 per cent.; O, 0.029 per cent.

Slag from this heat contained 48.42 per cent.  $\text{SiO}_2$ . The carbon content here increased, instead of decreasing, as would have been expected from the action of the ore. This was caused by the presence of the high-carbon iron scull. Therefore the same experiment was repeated when the vessel was clear and the iron hot.

See micrographs 16, 17, and 17d, Plate V.

Microsection 16, taken from Test 16, does not show an excessive amount of oxides, the large spots being slag inclusions.

Nos. 17 and 17d were both cut from Test 17; 17d was cut from that part of the block from which the drillings for analysis were taken. The steel is low in oxides and the impurities shown in the micrographs are manganese silicate, formed from the mixer scull contained in the vessel. An analysis made on Test 17 gave 0.058 per cent. manganese silicate.

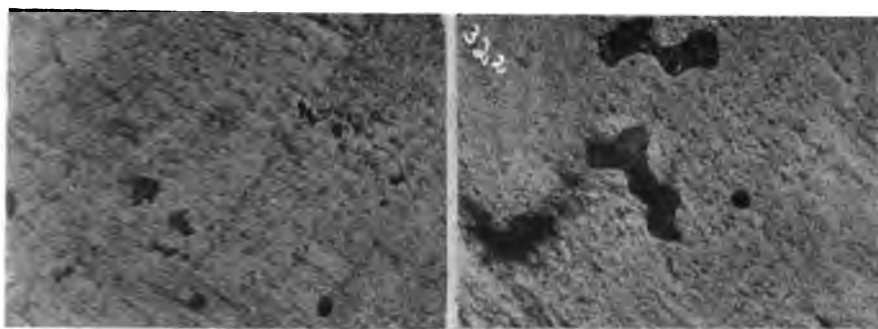


Fig. 16.  
C, 0.08 per cent. ;  
O, 0.024 per cent.

Fig. 17.  
C, 0.14 per cent. ;  
O, 0.029 per cent.

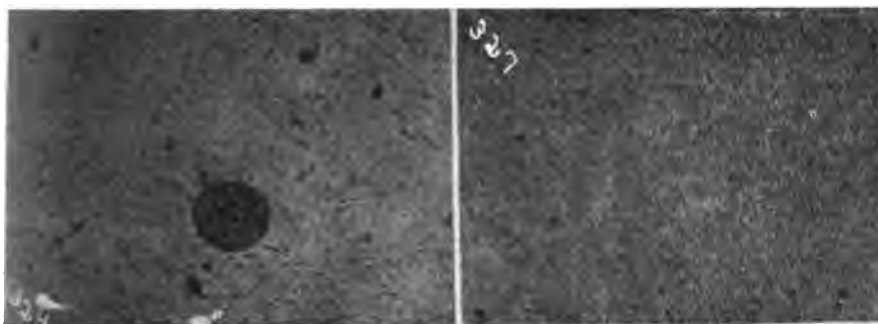


Fig. 17d.  
 $\text{SiO}_2$ , 0.058 per cent.

Fig. 18.  
C, 0.07 per cent. ;  
O, 0.038, 0.037 per cent

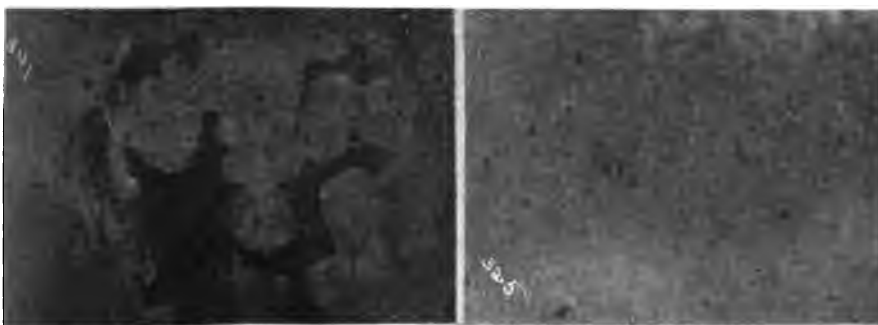


Fig. 19.  
C, 0.06 per cent.  
O, 0.028, 0.029 per cent.  
 $\text{SiO}_2$ , 0.052 per cent.

Fig. 20.  
C, 0.04 per cent.  
O, 0.033 per cent.

*Heat H:*—47,000 lb. of metal were blown soft and Test 18 taken. An analysis on Test 18 showed: C, 0.07 per cent.; O, 0.038 and 0.037 per cent.

As in Heat *G*, 1,000 lb. of ore were added to the vessel, and Test 19 taken two minutes after.

Test 19 analyzed: C, 0.06 per cent.; O, 0.028 and 0.028 per cent.

After holding five minutes longer, the ore still working in the bath, Test 20 was taken, which gave the following analysis: C, 0.04 per cent.; O, 0.033 per cent.

Slag taken from this heat contained 37.36 per cent.  $\text{SiO}_2$ , showing that the ore was passing into the slag as fast as melted. Ordinary Bessemer slags contain 60 to 62 per cent.  $\text{SiO}_2$ .

Note micrographs 18, 19, and 20, Plate V. The oxides found with the microscope check with those found by chemical analysis. Large spots of manganese silicate are seen in print No. 19. Test block No. 20 contained segregations of this impurity, but they were not photographed.

The drillings from Tests 17, 18, 19, and 20, after removing the oxygen by the hydrogen method, were used for determining oxides by the iron-iodide method. Only a trace of  $\text{FeO}$  was found, but residues of 0.058, 0.054, 0.052, and 0.050 per cent. were obtained, which, on examination, proved to be composed entirely of manganese silicate; hence the manganese silicate which is shown in micrographs 17, 17d, and 19. Ordinary steels contain a residue of about 0.01 per cent.

*Heat I:*—The opportunity presented itself of blowing a heat of Bessemer iron (phosphorus 0.090 per cent.). This was first blown for 0.75 to 0.85 per cent. carbon, for comparison with Tests 6, 7, 9, 12, and 13, and Test 21 was taken. An analysis of Test 21 showed: C, 0.830 per cent.; Mn, 0.30 per cent.; P, 0.120 per cent.; S, 0.031 per cent.; O, 0.017 per cent.

The heat was then blown soft, a violent reaction taking place, and Test No. 22 was taken. This test analyzed; C, 0.16 per cent.; Mn, 0.10 per cent.; P, 0.120 per cent.; S, 0.030 per cent.; O, 0.020 per cent.

While the vessel was held in the inclined position, 1,000 lb. of ore were added and, after allowing five minutes for reaction, Test 23, was taken. Test 23 analyzed: C, 0.10 per cent.; Mn, 0.03 per cent.; P, 0.120 per cent.; S, 0.030 per cent.; O, 0.040 per cent.

See micrographs 21a, 22a, 23a, 21f, 22f, and 23f, Plate VI. Microscopic sample No. 23 showed when polished the highest oxygen content. All these micrographs were taken after etching the samples.

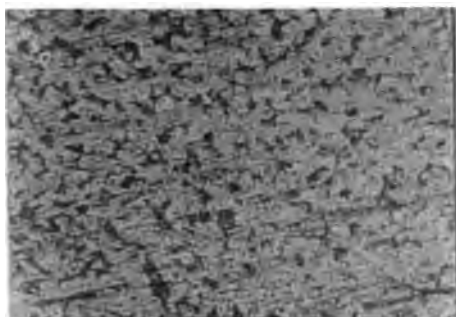


Fig. 22f.—Sample 22 forged and etched.  
O, 0.020 per cent.

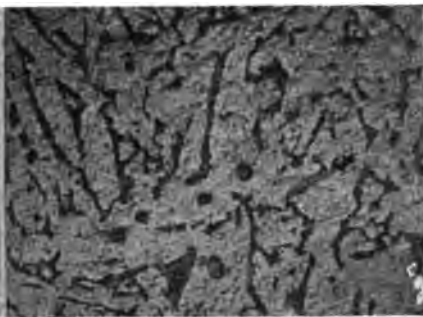


Fig. 22a.—Etched.  
C, 0.16 per cent. ;  
O, 0.020 per cent.



Fig. 21f.—Sample 21 forged and etched.  
O, 0.018 per cent.

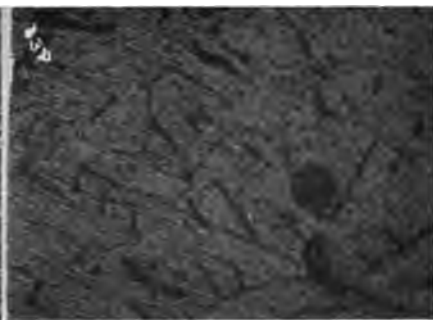


Fig. 23a.—Sample 23 etched.  
C, 0.10 per cent. ;  
O, 0.040 per cent.



Fig. 23f.—Sample 23 forged and etched.



Fig. 21a.—Sample 21 etched.

PLATE VI.—SAMPLES OF HEAT I ON BESSEMER IRON. ALL SECTIONS MAGNIFIED  
140 DIAMETERS.

Note the absence of iron phosphide in the high-carbon Test 21a, this being because the phosphorus is low as compared with all the previous heats.

These tests, 21, 22 and 23, all forged well. The high-carbon Test 21 was the only one in this high-carbon series which we were able to forge, due to the absence of phosphide of iron out of solution. Micrographs 21f, 22f and 23f show the etched structures of the respective forged test blocks; 23f contains a forged-out blow-hole.

For the purpose of verifying our analytical results, we ran check determinations for oxygen on the forged bars. The results are as follows:

*Oxygen Content.*

|                        | As Cast.  | As Forged. |
|------------------------|-----------|------------|
|                        | Per Cent. | Per Cent.  |
| Test Block No. 8.....  | 0.064     | 0.064      |
| Test Block No. 10..... | 0.027     | { 0.045    |
|                        |           | { 0.044    |
| Test Block No. 21..... | 0.017     | 0.018      |
| Test Block No. 22..... | 0.020     | 0.020      |
| Test Block No. 23..... | 0.040     | { 0.058    |
|                        |           | { 0.058    |

Forged tests 10 and 23 were very rough, and full of seams and laps (the blocks, as cast, being of a bad shape and difficult to forge properly), and the drillings were not clean. It was impossible to avoid these cracks and seams in drilling, which accounts for these tests (10 and 23) not checking with the original oxygen content in the blocks, as cast.

It will be noted how closely tests 8, 21, and 22 check; these forged tests were free from seams, and, therefore, the drillings were clean.

*Basic Open Hearth Heat, E-14,294:*—Test 24 was taken from a basic open hearth heat, just before adding ferro-manganese. The bath had been boiled down "flat" and held for some time. Following is the analysis: C, 0.05 per cent.; Mn, 0.05 per cent.; P, 0.023 per cent.; S, 0.055 per cent.; O, 0.024 per cent. It will be noted that the oxygen content of this heat is low, in spite of the fact that the heat was boiled down flat and held some time at a high temperature, thereby affording the best conditions for over-oxidation.

Micrograph 24 shows the oxygen in the sample as polished. This checks satisfactorily with the chemical analysis for this element.

A few results on finished open hearth steel might be of interest; the drillings for these determinations were not taken from test blocks, but from the finished product.

*Rail Steel.*

| Heat No.      | Oxygen.<br>Per Cent. |
|---------------|----------------------|
| E-21,276..... | 0.018                |
| E-17,244..... | { 0.015              |
|               | { 0.016              |
| E-22,377..... | 0.018                |
| E-17,441..... | 0.017                |
| E-21,428..... | 0.019                |
| E-24,202..... | 0.019                |
| E-26,065..... | 0.017                |

*Structural Steel (about 0.19 p. c. C.)*

| Heat No.      | Oxygen.<br>Per Cent. |
|---------------|----------------------|
| E-14,096..... | 0.024                |
| E-17,104..... | 0.022                |
| E-22,068..... | 0.019                |
| E-22,277..... | 0.015                |
| E-24,063..... | 0.014                |



FIG. 24.—SAMPLE FROM A BASIC OPEN HEARTH HEAT.  
C, 0.05 per cent. ; O, 0.024 per cent. No manganese silicate.

*Over-Oxidation of Steel.*

The following are a few results taken while working basic open hearth heats, making structural steel :

| Heat No.           | Preliminary Test No. 1,<br>Taken $\frac{1}{2}$ Hour Before<br>Tapping. | Preliminary Test No. 2,<br>Taken at Tapping, Just<br>Before Adding FeMn<br>to Furnace. | Drillings Taken from<br>Finished Beam. |
|--------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------|
|                    | Per Cent.                                                              | Per Cent.                                                                              | Per Cent.                              |
| 14,334—oxygen..... | 0.037                                                                  | 0.025                                                                                  | 0.022                                  |
| 24,092—oxygen..... | .....                                                                  | 0.030                                                                                  | 0.019                                  |

Another basic open hearth heat of 0.60 per cent. carbon was rolled into 4-in. square billets from a 10-in. square ingot. A section 1 in. thick was cut from the top, middle and bottom of this billet, corresponding to top, middle and bottom of the ingot, and drillings were taken from each section at one-third the distance from the surface. These drillings were run over a 20-mesh sieve to separate the fine from the coarse; oxygen was determined in each, and the average oxygen content calculated from the proportionate weight of fine and coarse.

|             | Drillings Remaining on<br>20-Mesh Sieve. | Drillings Passing<br>Through Sieve. | Calculated<br>Average. |
|-------------|------------------------------------------|-------------------------------------|------------------------|
|             | Oxygen.<br>Per Cent.                     | Oxygen.<br>Per Cent.                | Oxygen.<br>Per Cent.   |
| Top.....    | 0.017                                    | 0.027                               | 0.019                  |
| Middle..... | 0.010                                    | 0.020                               | 0.013                  |
| Bottom..... | 0.011                                    | 0.015                               | 0.012                  |

Oxygen determinations were run on a few 0.60 per cent. carbon crucible steels, and showed the following oxygen content:

Sample No. 1.—Test dipped out of a 90-lb. crucible and cast into a small test block: Oxygen, 0.014 per cent.

Sample No. 2.—Test dipped out of a 1-ton ladle; same heat as sample No. 1: Oxygen 0.014 per cent.

Sample No. 3.—Finished, rolled, bar: Oxygen, 0.010 per cent.

Sample No. 4.—Rolled bar picked out, at random, from the stock rack: Oxygen, 0.010 per cent.

Samples 1 and 2 were dipped out of the bath and cast into small molds, and were, therefore, somewhat porous, which no doubt accounts for their showing slightly higher oxygen than the finished bars, which were solid.

#### SUMMARY.

Every effort at over-oxidation was made, both by over-blowing and by ore addition.

1. The highest oxygen content obtained by over-blowing, were 0.074 (in Test 2); 0.064 per cent. (in Test 8) and 0.049 (in Test 11), notwithstanding that the tests were taken immediately, in order to get the highest oxygen possible. Also the tests were cooled quickly so that no gas could escape during casting.

2. While oxidizing with ore, we obtained 0.029, 0.028 and 0.033 per cent. oxygen, by taking test samples immediately after the ore begins working through the metal. When time was allowed for the oxygen to escape after the ore addition (as in Test 15), a content of 0.017 per cent. oxygen was found.

3. A basic open hearth heat, under oxidizing conditions, gave only 0.024 per cent. oxygen (Test 24).

4. Judging from the results obtained from heats *G* and *H*, it appears that either an unfinished heat or an over-ored heat will produce slag inclusions, such as manganese silicate, instead of iron oxide.

5. From these results, considering the manner in which they were taken, we may conclude that excessive oxygen leaves a bath of molten steel in a very short time. Also that deoxidation is readily effected by the addition of hot metal.



6. It will also be noticed that, under the same conditions, the higher the carbon the lower the oxygen.

7. Finally, it seems highly improbable that, under the usual conditions of Bessemer and open hearth practice, with the addition of recarburizers, that a steel of over 0.080 per cent. of oxygen can be obtained, and that the highest obtainable under any conditions, without recarburizing, can hardly be over 0.075 per cent. Results higher than this must be from drillings improperly taken, or from oxidation that occurred during teeming.



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1913, when Vol. XLVI of the *Transactions* will go to press. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## The Life of Crucible Steel Furnaces.

BY JOHN HOWE HALL, NEW YORK, N. Y.

(New York Meeting, October, 1913.)

THE recently announced run of three years, nine months and eleven days made by a crucible steel melting furnace of the Columbia Tool Steel Co., which is claimed as a world's record, brings forcibly to our attention the great improvements that have been made in the design, construction and operation of the Siemen's regenerative crucible melting furnace since its introduction in this country. Credit for this advance should be given to the furnace designer, the manufacturer of refractories, and the operators of the furnaces, whose persistent efforts and intelligent co-operation in attacking the problem have resulted so satisfactorily.

There are three factors that determine the life of a crucible furnace, or any other furnace for that matter: Design, nature of refractories and conditions of operation; (including the nature of steel melted) and to some extent these factors are interdependent. Thus, for instance, if a crucible furnace is to be operated single turn and allowed to cool off considerably at night, in order to save fuel, the use of clay-brick melting holes may be advisable, since silica brick is not well adapted to endure repeated heating and cooling. But the total life of a clay-brick melting hole is necessarily short. Again, if local conditions such as danger of flood make necessary the building of the furnace largely above ground, so that the radiation of heat is promoted, the cooling down of the furnace over the week ends, when no steel is melted, will be considerable—and the contraction of the furnace that results tends to wrack it to pieces.

The character of the metal being melted affects the life of the furnace to a great extent. Low-carbon steels and steels made from iron and charcoal require higher temperatures and much longer melting time than high-carbon steel or steel made largely from scrap; the life of the furnace will be shorter, and the number of heats melted will be much less, when such materials are melted.

The figures available, showing the life of furnaces, are for this reason especially not strictly comparative, since the variations in the

steel melted undoubtedly affect the life to a greater or less extent. Probably, however, the method of handling is as important a factor as the material melted in determining the life of a furnace of given design and construction.

Originally the melting holes of the regenerative gas fired crucible furnace were lined with first quality firebricks. One of the leading builders of furnaces reports that when the Siemens furnace was first introduced in this country the life of a furnace was from four to six weeks; the short life was due in great part to lack of familiarity with the furnace on the part of the men in charge. As the workmen grew more skillful in handling the furnaces, this life was gradually increased to six months by retopping, and in some cases to nine months or one year, by retopping twice (by retopping is meant rebuilding the upper portions of the melting holes). These records were made a number of years ago in four or more leading Eastern shops.

A prominent manufacturer of refractory materials gives the following figures for the life of melting furnace in several different shops with melting holes lined with first quality firebrick.

| Plant.      | Life of Furnace in Months. |
|-------------|----------------------------|
| 1 . . . . . | 3 to 4                     |
| 2 . . . . . | 4                          |
| 3 . . . . . | 5 to 6                     |
| 4 . . . . . | 6                          |
| 5 . . . . . | 12                         |

No details of design, or nature of steel being made are given, but the average very short life of furnaces with clay-brick melting holes is quite evident.

When the melting holes are lined with silica brick, the life of the furnace is greatly increased, as the figures in the following table show :

| Authority.                    | Plant. | Mo.        | Life of Furnace<br>Days. | Heats. | No. F's. |
|-------------------------------|--------|------------|--------------------------|--------|----------|
| Furnace builder,              |        |            |                          | 2,000  | Average  |
| Crucible steel maker, . . .   | A      | 6-15       |                          |        | Average  |
| Crucible steel maker, . . .   | B      | 14-18.5    |                          |        | Average  |
|                               | B      | 18 average |                          |        | (1)      |
| Crucible steel maker, . . .   | C      | 18         |                          |        | (1)      |
|                               | C      | 19         |                          |        | Average  |
|                               | C      | 15-21      |                          |        | (1)      |
|                               | C      | 18 average |                          |        | (1)      |
| Manufacturer of refractories, | D      | 14         |                          |        | (1)      |
| Manufacturer of refractories, | D      | 19         |                          |        | (1)      |
| Manufacturer of refractories, | D      | 24         |                          |        | (1)      |
| Manufacturer of refractories, | E      | 12         | 0                        | 1,418  | (1)      |
| Manufacturer of refractories, | E      | 14         | 12                       | 1,720  | (1)      |
| Manufacturer of refractories, | E      | 16½        | 0                        | 1,897  | (1)      |
| Manufacturer of refractories, | E      | 17         | 22                       | 2,126* | (1)      |
| Manufacturer of refractories, | E      | 18         | 4                        | 2,186  | (1)      |
| Manufacturer of refractories, | F      | 28         | ...                      | .....  | (1)      |
| Manufacturer of refractories, | F      | 45         | ...                      | .....  | (1)      |
| Manufacturer of refractories, | G      | 11         | ...                      | .....  | (1)      |

\* Heats made as follows : Projectiles, 1,325 heats ; high-speed steel, 325 heats ; magnet steel, 250 heats ; chrome-vanadium steel, 40 heats ; nickel steel, 25 heats ; castings, 15 heats ; carbon steel, 70 heats ; miscellaneous, 75 heats ; total, 2,126 heats.

These figures are not improbably duplications, in some cases; that is, no doubt the same furnace may occur in the reports of both steel maker and maker of refractories.

Compared with these records we have that of the Columbia Tool Steel Co., of a continuous run of 45 months and 11 days, for a total of 6,290 heats; the material melted is said to have been "high-grade high-carbon tool steel." The high-carbon steel of course does not require as high a heat as, for instance, cast steel of 0.25 per cent. C or alloy steels (Ni or Cr-V.) of 0.80 per cent. C., but probably the reasons for long life of this furnace are first, good design; second, good refractories; third, careful handling.

There are several features of the design of this furnace that are worthy of notice. A strong foundation was provided to guard against settling and consequent wracking of the furnace; the furnace was set with the working floor only about 31 in. above the ground level, so that the radiation of heat was minimized, tending to discourage contraction of the furnace and consequent wracking of the brick work; and the walls between checker chambers which are frequently but 12 in. thick were made 18 in. thick to insure against the leakage of gas into air chambers and flues that commonly occurs when the furnace grows old. The holes were lined with silica brick of standard make; breast walls, flues between checker chambers and melting holes, checkers, etc., were of first quality clay or firebrick.

The Columbia Tool Steel Co. states that great pains were taken in the operation of this furnace to maintain the temperature as uniform as possible at all times, especially over the idle week-end; and that although several new tops have been put on the melting holes, and a new middle wall built in, the furnace was when shut down for general repairs, still in fairly good shape. This is a remarkable record, after such a long campaign.



TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.  
[SUBJECT TO REVISION].

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the Butte meeting, Aug. 18 to 21, 1918, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Oct. 1, 1918, when Vol. XLVI. of the *Transactions* will go to press. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## Cement Materials and the Manufacture of Portland Cement in Montana.

BY W. H. ANDREWS,\* TRIDENT, MONT.

(Butte Meeting, August, 1918.)

THE constantly increasing consumption of Portland cement in the State makes the above subject of particular interest at this time. The increasing demand is due to the rapid settling of the country and the fact that new uses are being found frequently for the above named commercial article. The industry is one that is bound to grow as the population increases, and this being the case it may be well at this time to consider briefly the matter of the chemical and physical composition of proper raw materials.

A cement mixture is one that contains approximately 75 per cent. carbonate of lime, 15 per cent. silica, and 5 to 7 per cent. alumina and iron oxides; the other elements being magnesium carbonate and small quantities of the rarer elements generally associated with limestone deposits. It can be readily seen from the above composition that it is possible to build up this mixture from a number of different materials.

*First.*—A rock high in carbonate of lime can be mixed with clay or shale in such proportions as to bring about the desired composition; the chief difficulty in the building up of such a mixture is that it is hard to find a clay or shale in which the silica-alumina ratio lies between 4 to 1 and 8 to 1 and at the same time shows physical characteristics which will make certain its adaptability to the practical manufacture of Portland cement. Very often clays or shales are found which are right chemically but contain large quantities of grit or free silica. Such clays or shale must be ground to extreme fineness in the mixture in order to make the silica and alumina combine with the lime when the mixture is burned. On the other hand, clays or shales are often found that have the proper physical characteristics but in which the amount of alumina is too great.

*Second.*—A mixture can be built up of different limestones some of

\* Non-member.

which run above the 75 per cent. requirement and others below; these limestones, however, must contain the right proportions of silica and alumina and must possess the proper physical characteristics.

*Third.*—A large percentage of the Portland cement marketed in the country was formerly manufactured from marl and clay, but on account of the low specific gravity of the marl and the large organic content, this method has given way to the making of cement from different kinds of rock.

*Fourth.*—A limestone containing approximately the 75 per cent. carbonate of lime required is sometimes, but rarely, found. Such a stone is called "cement rock." If such a deposit contains the silica and alumina in the proper ratio and the corrective materials occur in the same quarry, the property is of value. It can be readily seen that a natural mixture can be handled in such a manner as to produce the best possible product with the least trouble in the manufacture.

An example of cement rock is the Trenton rock of the Lehigh valley, Pennsylvania, from which large quantities of Portland cement are manufactured. It must be borne in mind, however, that in all of the above named methods the materials used must be low in magnesia and free from sulphur.

In regard to the process of manufacture it might be said that the advancement has been remarkable during the past few years. The tendency has been toward fewer units, with larger capacity per unit. One of the large rotary kilns of to-day will do the work of five of the kilns in common use 10 or 12 years ago. The same is true of machinery for the preparation of the raw materials and the grinding of the finished product.

Montana, up to date, has but one cement plant in operation: that of the Three Forks Portland Cement Co., located at Trident, just below the Three Forks of the Missouri river on the Northern Pacific Railway. This plant manufactures the "Red Devil" brand of cement and has been in active operation since June, 1910. This plant uses for its raw materials a cement rock of Devonian age.

The mill was constructed by F. L. Smith & Co. and is an example of an up-to-date plant. The rock is loaded in the quarry by two 80-ton Bucyrus steam shovels into bottom-dump steel cars. These cars are hauled by a steam locomotive a short distance to the crusher house, where they are discharged into a No. 9 crusher which has a much greater capacity than the mill's regular requirement. This crusher reduces the rock to about 2-in. size and under; the oversize is sent to a smaller crusher before going to the blending bins.



After being crushed, the rock is elevated to the top of what are known as blending bins—these are eight in number, having a capacity of 200 tons each, four being on one side of the scale hopper and four on the other side. The rock running higher in carbonate of lime than the required mix is kept on one side of the mixing scales and the rock lower in carbonate of lime than the required mix is kept on the other side. As the rock drops to the bins, it passes through equalizing drums and is automatically sampled. The resulting sample is ground and removed to the laboratory for chemical analysis.

The rock in the different bins having been carefully analyzed, the mixture is calculated by the chemist. The rock is then conveyed to the scale hoppers by belt conveyors which travel underneath the bins. Here, the high and low rock is weighed off in the proper proportion. By the method of sampling in use, it is possible at all times to keep the cement mixture the same. From the scale hoppers the rock is elevated to a bin over the dryer. The rock in passing through the dryer is deprived of its moisture. This puts it in condition for fine grinding. From the rotary dryer, which is fired by producer gas, the rock is elevated to bins over grinding mills, called "kominuters."

The kominuters are large drums, revolving on horizontal shafts. The drums are lined with perforated steel plates and surrounded by screens set at such an angle as to return automatically all coarse material to the mill for regrinding. The grinding is accomplished by large steel balls which are given a tumbling action as the mill revolves. The raw rock is ground in these mills to a fineness of about 80 per cent. passing a 20-mesh screen. Samples of the product of these mills are taken every two hours to the laboratory for fineness test and chemical analysis.

From the kominuters the partially ground material is elevated to bins over the tube mills, into which mills it passes for the finished grinding. The tube mills are 22 ft. long by 6 ft. in diameter. These mills are divided into two compartments by a perforated plate placed 5 ft. from the discharge end. The large end of the mill is filled with pebbles and the small compartment with what are known as cylpebs. These cylpebs are small cylindrical pieces of steel. Both compartments are filled nearly half full with pebbles and cylpebs. The mills make about 25 rev. per min., the material being fed constantly through a small screw conveyor from the bin to the pebble end of the mill. The cylpebs increase the efficiency of the mill, making possible larger capacity and greater fineness.

The raw mix, which is finished to a fineness of 90 per cent. passing a 100-mesh sieve, is sampled and analyzed every two hours, during

the 24, and passes through screw conveyors and bucket elevators to the bins over the rotary kilns. The kilns are two in number, 9.5 ft. in diameter by 140 ft. in length and having a combined capacity of 1,600 to 1,800 barrels daily.

The fuel used is powdered coal, mined at Red Lodge. This coal is ground to a fineness of 95 per cent. passing 100-mesh sieve and is blown into the front end of the kilns by an air pressure furnished by large fans. The coal therefore burns with a flame very much like gas, raising the heat in the lower part of the kilns to about 3,000° F.

The raw material is fed into the upper end of the kiln through a screw conveyor and as the kiln is set on a slight angle and revolves slowly, the mix travels toward the discharge end. As it passes through the heat zone the carbonic acid is driven off and the lime carbonate is changed to lime silicates and aluminates. It can be seen that careful preparation of the raw materials is necessary to bring about the proper combination of the lime, silica and alumina. During this process, the powdered mix undergoes a physical as well as a chemical change. It enters the kiln a light colored powder and is discharged in the form of white hot clinkers, changing to dark green and black when cooled, and varying in size from that of a small pea to several inches in diameter. Chemically, these clinkers are now Portland cement, but it is necessary to grind them to a very fine powder in order to have commercial Portland cement.

The clinker passing from the kilns, white hot, is caught in a large elevator and carried to a rotary cooler. The cooling is accomplished by natural draft. From the cooler, it is elevated and discharged into the storage yard. From the yard, the clinker is taken through a tunnel by belt conveyor and elevators to the final grinding room. The grinding of the finished product is accomplished by kominuters and tube mills, which have been described in the grinding of the raw materials. It is necessary at this stage of the manufacture to add 2 to 3 per cent. of raw gypsum to regulate the setting time.

As the finished cement drops from the tube mills it is sampled every two hours and taken to the laboratory for physical tests and chemical analysis. The cement then passes by means of screw and belt conveyors and bucket elevators, to the stock house, where it is stored until required for shipment.

The stock house is of reinforced concrete and has a capacity of 40,000 barrels of cement. It is divided into five bins or compartments. From these stock-house bins, the cement is conveyed and elevated to eight packing hoppers, each having a capacity of about 1,000 barrels, from which it is fed to the packers.

The product is shipped in duck and burlap bags, 95 lb. to the sack, and four sacks to the barrel. As each car is loaded, samples representing the contents are taken and sent to the laboratory for confirming tests. From the time the raw material leaves the quarry until the finished product goes into the cars, it is not touched by hand.

Cement machinery is ponderous and the wear and tear tremendous—competent superintendence and skilled operators are necessary in the manufacturing end. As has been mentioned elsewhere in this article, the process of cement manufacture has undergone a wonderful evolution during the past few years. Old style mills cannot keep pace with the more modern ones, either in the quantity of output or quality of the finished product. Specifications are now drawn up with a view of finding every possible weakness in the cement as marketed. The strength required is greater, and realizing the importance of sand carrying power, the railroads and different municipalities are demanding greater fineness. The Auto Clave test has been invented to prove beyond question the absolute soundness of Portland cement. These requirements can only be met by the mills that are modern or have kept up-to-date and the public is guaranteed safety when it uses cement that has passed standard specifications, provided the work is properly done and the proper aggregates are used.

Cement materials are rather widely scattered throughout the State, the difficulty being to find all the materials together and the location suitable with regard to market. Doubtless, in time other plants will be built in the State, but at present the one mill in operation is easily able to supply the State and in fact is obliged to market part of its product in adjoining States.



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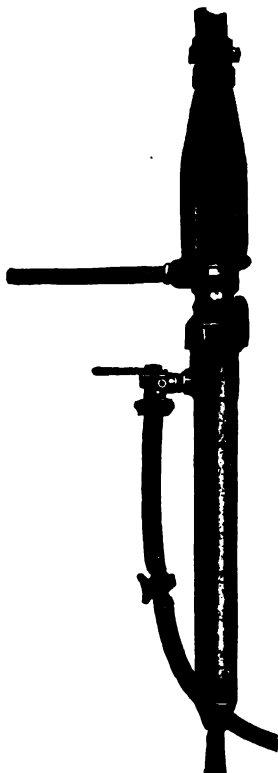
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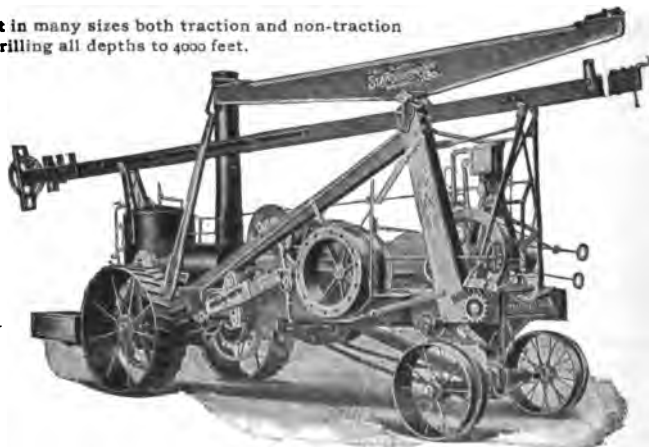


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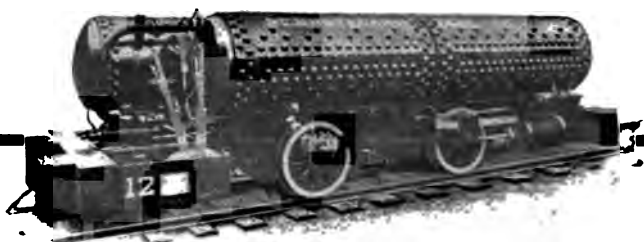
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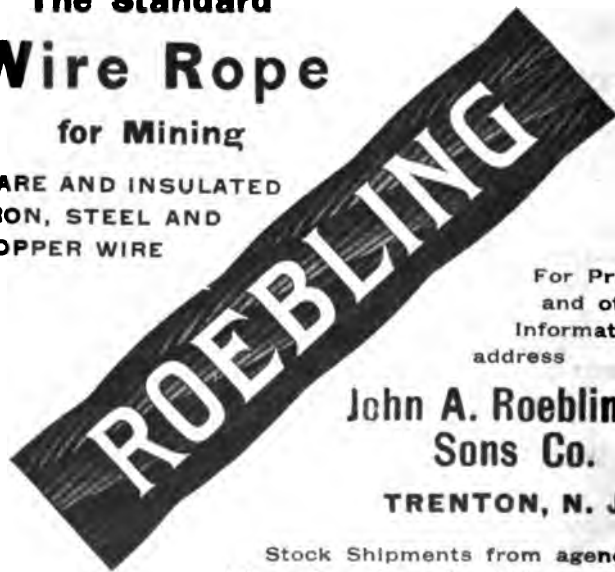
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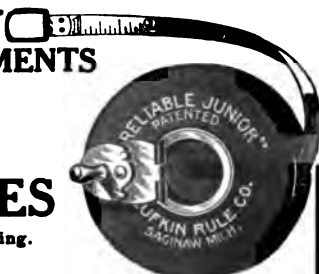
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*Dated* \_\_\_\_\_ *191*

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SEC. 1. The membership of the Institute shall comprise four classes, namely: 1. Members; 2. Honorary Members; 3. Associates; 4. Junior Members. \* \* \*

SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely: as Members, all professional mining engineers, geologists, metallurgists, o. chemists, and all persons actively engaged in mining and metallurgical engineering, geology, or chemistry; as Associates, all persons desirous of being connected with the Institute who in the opinion of the Board of Directors are suitable.

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# Bulletin of the American Institute of Mining Engineers.



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OPERATING COST, AND A VERY  
LOW RATE OF DEPRECIATION."**

**—From Chile Mills vs. Hardinge Mills,  
paper presented before the Butte meeting  
of the A. I. M. E., by Mr. Robert Franke,  
of Miami, Ariz., Aug., 1913.**

**HARDINGE CONICAL MILL CO.  
50 CHURCH STREET  
NEW YORK**

**LONDON  
563 Salisbury House**

**CABLES  
Halharding, New York**

Aug. 14, 1916.  
Bequest of  
Erasmus Darwin Leavitt.

# BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.

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Subscription (including postage), \$10 per annum; to members of the Institute, public libraries educational institutions and technical societies, \$5 per annum. Single copies (including postage), \$1 each; to members of the Institute, public libraries, etc., 50 cents each.

Entered as second class matter, October 16, 1911, at the post office at Philadelphia, Pa., under the Act of March 3, 1879.

**New York Meeting, October 16 and 17, 1913.**—The One Hundred and Sixth meeting of the Institute for the reading and discussion of professional papers will be held in New York City, on Thursday and Friday, October 16 and 17, 1913. Headquarters will be at the Institute office in the Engineering Societies Building, 29 West 39th Street. The sessions will be held in one of the assembly rooms of the building. Because of the many valuable papers on iron and steel obtained with the assistance of the Iron and Steel Committee, which papers could not appropriately be presented and discussed at the Montana meeting, this October meeting of the Institute is held for the purpose of reading and discussing these papers, most of which will be printed and distributed in advance. The members of the following societies have been invited to attend the meeting, and several have accepted and declared their intention of taking part in the proceedings: American Society for Testing Materials, American Iron and Steel Institute, American Society of Mechanical Engineers, American Society of Civil Engineers, American Institute of Electrical Engineers, American Foundrymen's Association. The meeting will be conducted under the auspices of the Iron and Steel Committee, and the latest revised program of the proceedings will be found on page xi, under the notes of this Committee.

Five or six important papers on iron and steel subjects are already assured for the February meeting of the Institute, and a list of other manuscripts already approved for presentation at this meeting is given on p. v.

**Nominations for Officers.**—The Committee appointed by the Board of Directors to nominate officers for the Institute for the year 1914 desires that every member participate in the work by offering suggestions and proposing names for the various offices, thereby obtaining the best ticket that can be recommended.

The officers to be elected at the annual meeting in February, 1914, are:

One officer, known as Director and President.

Two officers, known as Director and Vice-President.

Five officers, known as Director.

The attention of members is called to Articles V and VII of the Constitution, and to By-Law XIII, which reads as follows:

"The Geographical districts to be considered by the Committee on Nominations shall be as follows, until otherwise ordered by the Board.

District No. 1. New England, New York, and New Jersey, excepting New York City and district, which is provided for in the Constitution. [N. B.—New York City and district is designated District 0.]

District No. 2. Pennsylvania.

District No. 3. Ohio, Indiana, Illinois, Iowa, and Missouri.

District No. 4. Minnesota, Wisconsin, and Michigan.

District No. 5. Montana, North and South Dakota, Wyoming, Nebraska, Kansas, Washington, Oregon, Idaho, and Alaska.

District No. 6. California and Nevada.

District No. 7. Utah, Colorado, Arizona, and New Mexico.

District No. 8. Louisiana and Texas.

District No. 9. Other Southern States and District of Columbia.

District No. 10. Mexico.

District No. 11. Canada."

An excerpt from Article VII of the Constitution reads as follows:

"In making such selections [namely, the 8 Directors to be elected], the Nominating Committee shall, so far as practicable, distribute the representation on the Board geographically, so that seven members shall be residents of the district including New York City and the territory within a radius of fifty miles of the headquarters of the Institute, and one member a resident of each of the geographical districts enumerated in the By-Laws."

The officers of the Institute whose terms expire are as follows:

President, Charles F. Rand (not eligible for re-election).

Past President, Charles Kirchhoff.

Vice-Presidents, Karl Eilers, District 0; Waldemar Lindgren, District 1.

Directors, James Douglas, District 0; James Gayley, District 0; Albert R. Ledoux, District 0; Charles W. Merrill, District 6; and C. Snelling Robinson, District 3.

It is hoped that the members of the Institute will help the Committee to the utmost by making suggestions and proposals as requested above, which should be sent to the Chairman of the Nominating Committee, John Hays Hammond, 71 Broadway, New York, N. Y.

JOHN HAYS HAMMOND,  
*Chairman, Nominating Committee.*

This Committee is required to submit its Nominations to the Board of Directors on October 24.

## EMMONS VOLUME ON ORE-DEPOSITS.

*A continuation of the "Posepny" Volume.*

Comprising papers descriptive of ore-deposits and discussions of their origin, edited, with an introduction, by Dr. S. F. Emmons. The volume contains also a Biographical Notice of Dr. Emmons by his associate and friend, Dr. George F. Becker, and a comprehensive Bibliographical Index of the Science of Ore-Deposits, prepared by Prof. John D. Irving, of the Sheffield Scientific School of Yale University. Dr. Emmons had finished his editorial work and written his Introduction before his lamented death in 1910; and the Volume contains his last words upon the subject to which he had given the work of his life, and on which he was justly regarded as the foremost authority.

*Contents.*

- Genesis of Certain Ore-Deposits. By S. F. EMMONS.  
 Structural Relations of Ore-Deposits. By S. F. EMMONS.  
 Geological Distribution of the Useful Metals in the United States. By S. F. EMMONS. Discussion, by JOHN A. CHURCH, ARTHUR WINSLOW, S. F. EMMONS, and WILLIAM HAMILTON MERRITT.  
 Torsional Theory of Joints. By GEORGE F. BECKER. Discussion, by H. M. HOWE, R. W. RAYMOND, C. R. BOYD, and GEORGE F. BECKER.  
 Allotropy of Gold. By HENRY LOUIS.  
 Superficial Alteration of Ore-Deposits. By R. A. F. PENROSE, JR.  
 Some Mines of Rosita and Silver Cliff, Colorado. By S. F. EMMONS.  
 Genesis of Certain Auriferous Lodes. By JOHN R. DON. Discussion, by JOSEPH LE CONTE, S. F. EMMONS, G. F. BECKER, ARTHUR WINSLOW, W. P. BLAKE, and J. R. DON.  
 Influence of Country-Rock on Mineral Veins. By WALTER HARVEY WEED.  
 Igneous Rocks and Circulating Waters as Factors in Ore-Deposition. By J. F. KEMP.  
 Consideration of Igneous Rocks and Their Segregation or Differentiation as Related to the Occurrence of Ores. By J. E. SPURR. Discussion, by A. N. WINCHELL.  
 Chemistry of Ore-Deposition. By WALTER P. JENNEY. Discussion, by JOHN A. CHURCH.  
 Ore-Deposits near Igneous Contacts. By WALTER HARVEY WEED. Discussion, by W. L. AUSTIN.  
 Ore-Deposition and Vein-Enrichment by Ascending Hot Waters. By WALTER HARVEY WEED.  
 Basaltic Zones as Guides to Ore-Deposits in the Cripple Creek District, Colorado. By E. A. STEVENS.  
 Geological Features of the Gold-Production of North America. By W. LINDGREN. Discussion, by W. G. MILLER and W. L. AUSTIN.  
 Osmosis as a Factor in Ore-Formation. By HALBERT POWERS GILLETTE.  
 Ore-Deposits of Sudbury, Ontario. By CHARLES W. DICKSON.  
 Genesis of the Copper-Deposits of Clifton-Morenci, Arizona. By W. LINDGREN.  
 Copper-Deposits at San Jose, Tamaulipas, Mexico. By J. F. KEMP.  
 Magmatic Origin of Vein-Forming Waters in Southeastern Alaska. By A. C. SPENCER.  
 Genetic Relations of the Western Nevada Ores. By J. E. SPURR.  
 Are the Quartz Veins of Silver Peak, Nevada, the Result of Magmatic Segregation? By J. B. HASTINGS.  
 Occurrence of Stibnite at Steamboat Springs, Nevada. By W. LINDGREN.  
 Summary of Lake Superior Geology with Special Reference to Recent Studies of the Iron-Bearing Series. By C. K. LEITH.  
 Geological Relations of the Scandinavian Iron-Ores. By H. SÖGREN.  
 Formation and Enrichment of Ore-Bearing Veins. (With Supplementary Paper.) By GEORGE J. BANCROFT.  
 Distribution of the Elements in Igneous Rocks. By H. S. WASHINGTON.  
 Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold-Deposits of the United States. By W. H. EMMONS.  
 Cognate Papers.  
 Bibliography of the Science of Ore-Deposits. By J. D. IRVING, H. D. SMITH, and H. G. FERGUSON.

The volume contains 1002 pages. Price, bound in cloth, \$5; in half morocco, \$6. Both the Emmons and the Posepny Volumes on Ore-Deposits, bound in cloth, \$8; in half morocco, \$10.

**READY FOR DISTRIBUTION.**

## BOARD OF DIRECTORS.

*Meeting, Aug. 20, 1913, Butte, Montana, at 12.45 p.m.*—On the written request of 27 members of the Institute residing in Montana, the Montana Local Section was established, and the following Committee was appointed by the President of the Institute to complete the organization: E. P. Mathewson, *Chairman*; Frank M. Smith, *Vice-Chairman*; D. C. Bard, *Secretary*, Montana State School of Mines, Butte, Mont., Oscar Rohn, James L. Bruce.

The President reported the appointment of a Committee on Mining Law, the names of whose officers and members are given on page xxxv of this *Bulletin*, and these appointments were approved.

It was voted: That the Committee on Mining Law be requested to establish a Sub-Committee on Censorship, a majority of whom shall be lawyers; and, further, that no paper on mining law be recommended for publication to the Committee on Papers and Publications, unless it is previously approved by the Sub-Committee on Censorship of the Committee on Mining Law.

The President reported progress in the matter of co-operation between the Institute and the United States Bureau of Mines, through Committees of the Institute.

The President reviewed the history of plans for a union or affiliation with the Mining and Metallurgical Society of America, and the following minute was then adopted:

"The Board of Directors of the American Institute of Mining Engineers has carefully considered for several months the question of union or affiliation with the Mining and Metallurgical Society of America; and, while at an earlier time and under other circumstances, such a union might have been accomplished, yet under present circumstances the Directors of the Institute deem such union inexpedient.

"While thanking the Mining and Metallurgical Society of America for its consideration of the matter, we believe that further discussion of the subject will serve no useful end, and we conclude it best that the Society and the Institute continue their useful functions and friendly relations side by side, as heretofore."

It was voted that, beginning with the September *Bulletin*, 5,200 copies be published each month, to supply the increased demand.

*Meeting, September 26, 1913, in New York.*—The President reported the appointment of a Committee on Petroleum and Gas, the names of whose officers and members are published on page xxxv, and these appointments were then approved.

Karl Eilers was appointed by the Board a member of the Committee on Membership, in place of Walter R. Ingalls, resigned.

It was voted to accept the offer of the *Mining Magazine*, of London, in regard to selling copies of the Emmons Volume on Ore Deposits.

It was voted to grant an exchange of publications with the Gesellschaft Deutscher Metallhütten-und Bergleute.

It was voted that the Committee on Management of the International Engineering Congress, 1915, be asked to consider seriously having metallurgy given the same importance as mining and geology in the proceedings and publications of this Congress.

It was voted to authorize the President to establish an additional technical committee to be called Committee on Non-Metallic Minerals.

Professor Kemp reported on behalf of the Library Committee, and stated that the Committee would ask for an increase of the Institute's



appropriation from \$4,500 to \$5,000 for the next calendar year; he also made a statement regarding a suggestion to establish in New York City a Downtown Branch of the Library.

The President requested authority to appoint a Committee on Junior Members and Affiliated Student Societies. The authority was voted.

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### MANUSCRIPTS RECEIVED BY THE SECRETARY.

The following papers have been accepted for publication in the *Bulletin*. The list is here published in order that application may be made, if desired, for one or more of these papers for discussion by Local Sections of the Institute. Whether these papers are or are not discussed by Local Sections, they will be presented at the February meeting of the Institute in New York, N. Y., and advance discussion by individuals is requested.

Milling versus Hand-Sorting of Lead Ore, by R. S. Handy (Presented at Spokane Local Section).

The Chloridizing-Roasting of Cuprous Pyrites Cinder Preliminary to the Extraction of Copper by Leaching. Otherwise known as the Wet Process, by Utley Wedge (Presented at the Boston Local Section).

Mining and Mining Methods in the Southeastern Missouri Disseminated Lead District, by H. A. Guess.

Notes on the Genesis of the Mercury Deposits of the Pacific Coast, by J. Allen Veatch.

The Use of Oxygen Helmets for Mine Fires, by E. P. Dudley (Presented at Spokane Local Section).

The Substitution of Air for Water in Diamond Drilling, by Ralph Wilcox.

Disposition of Natural Resources, by George Otis Smith.

Nickel Deposits in the Ural, by H. W. Turner.

Lead-Silver Mines of Gilmore, Lemhi County, Idaho, by Ralph Nichols.

Notes on an Iron Ore Deposit near Hong-Kong, China, by C. M. Weld.

The Injection of Cement Grout into Water-Bearing Fissures, by F. Donaldson.

The Burning of Coal Beds in Place, by Alexander Bowie.

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### POSITIONS VACANT.

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Position of laboratory assistant in metallurgy, pyrometry, and physical testing is vacant. Salary \$80 to \$100 to start. Knowledge of metallography desirable.

Opening for a mine superintendent familiar with stoping methods on narrow gold quartz veins; also for a superintendent of a 50-ton fine-grinding cyanide mill. College man under 40 preferred.

Position in sales department is open for a mining engineer with experience in mine ventilation and possessing some knowledge of fan design; one competent to lay out ventilating systems to meet various conditions.

**ENGINEERS AVAILABLE.**

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

**COAL**—A member, aged 38, with 23 years' experience in mining and preparing coal, and designing plants and mining machinery, is open for engagement. For nine years has held the positions of Superintendent and General Superintendent, and later was in charge of 15 mines. No. 1.

A technical graduate, aged 32, with experience as manager and operator and consulting engineer for gold, silver, and copper mines and cyanide mills in Colorado, Nevada, Canada, and Mexico, desires permanent engagement. No. 2.

A technical graduate, who has held positions from assayer and surveyor to mine manager, and has had three years' experience in mining in Utah and Colorado, and six years' experience in Alaska, Tennessee, and Ontario, is prepared to accept a position as mining engineer in any part of the world. Is familiar chiefly with gold, silver, lead, and copper. No. 3.

A technical graduate with experience in engineering drafting and four years' experience as testing engineer in fuel and coal, would like to make a change in his position. No. 4.

A member, technically educated, with 20 years' practical experience as engineer, assistant superintendent, superintendent, and manager of large mines and mills on construction and operation, also experience in mine examination, is open to engagement. No. 5.

Metallurgist of 18 years' experience in Mexico with large plants is open to engagement. Last position, superintendent of copper smelting works. Best line, copper and lead smelting, but also experienced in mine valuation and ore-treatment investigation work. Speaks Spanish. No. 6.

Member, graduate mining engineer, experienced in mine and mill work, geology and field work, one year in the hydrometallurgy of copper, is open for engagement. No. 7.

A member, technical graduate, with nine years' mining experience as assayer, engineer, foreman, manager's assistant, and superintendent of large development and operating mining companies in the United States and Mexico, is open for engagement. No. 8.

Young man, recent graduate in mining and geology, desires position. No. 10.

Fuel expert, graduate chemist, four years' experience in chemical routine and research work on fuels and chemical side of engine-room and boiler-room problems. Classification and valuation of fuels and solution of feed water troubles a specialty. No. 11.

Metallurgist, experienced in the handling of carbon, alloy and tool steels, desires a position with a steel company, preferably as traveling sales metallurgist. No. 12.

Graduate chemist, with seven years' experience in analytical work, including gold, silver, zinc, fuels, desires a position, preferably in the West, as chemist or foreman in a metallurgical plant. No. 13.

Metallurgist and chemist, technical graduate, seven years' experience in copper and lead smelting, and eight years' experience in assaying and general analytical work, desires to invest capital with services. West coast of United States or Canada preferred. No. 14.

Mining engineer with 23 years' practical experience desires to make a change. No. 15.

Technical graduate, seven years' experience smelting, mining and managing copper plants, is open for engagement. No. 16.

## PERSONAL.

(Members are urged to send in for this column any notes of interest concerning themselves or their fellow-members.)

Members who registered at Institute headquarters during September:

William B. Phillips, Austin, Texas.  
Olof Wenstrom, Boston, Mass.  
Anthony F. Lucas, Washington, D. C.  
P. H. Griffin, New York, N. Y.  
H. N. Lawrie, Portland, Ore.  
Clarence P. Linville, Everett, Pa.

Will L. Clark, Jerome, Ariz.  
Robert H. Richards, Boston, Mass.  
Hennen Jennings, Washington, D. C.  
Waldemar Lindgren, Boston, Mass.  
C. Snelling Robinson, Youngstown, O.  
E. P. Ross, Johnson, Tenn.

Members of the XII International Geological Congress who made the Institute Office their headquarters while in New York:

A. Bigot, Caen, France.  
J. Caillebotte, Paris, France.  
John Ashworth, Manchester, England.  
T. Dahlblom, Falun, Sweden.

E. Gentil, Paris, France.  
H. Saint-Clivier, Paris, France.  
Tadasu Hiki, Kioto, Japan.  
L. Milch, Greifswald, Germany.

**Prof. Albert Sauveur**, of Harvard University, has been awarded the Elliott Cresson Gold Medal by the Franklin Institute, which is the highest award in the gift of the Institute, "in recognition of his numerous and important contributions to the science of metallography and the influence he has exerted in bringing this science into practicable and exceedingly useful application in the iron and steel industry."

**Joseph A. McDonald**, for some years Assistant General Superintendent of the Ohio works of the Carnegie Steel Co., Youngstown, Ohio, has been made General Superintendent of the Cambria department of the Cambria Steel Co.

**Charles H. MacNutt**, of London, England, has gone to take charge of the Burma Mines, Ltd., Northern Shan States of Burma.

**H. N. Lawrie**, consulting mining geologist and Chairman of the Oregon Bureau of Mines and Geology Commission, has come East to represent that State at the Geological Convention of the National Conservation Exposition, held Sept. 19 at Knoxville, Tenn., and the convention of the American Mining Congress, to be held Oct. 20 to 24, in Philadelphia.

**Prof. Solon Shedd**, Department of Geology, Washington State College, is in Baker county, Oregon, looking over the situation preparatory to making a topographic map of the State for the Oregon Bureau of Mines and Geology.

**Bancroft Gore**, has been appointed Professor of Metallurgy at the Montana State School of Mines.

**Robert N. Dickman** has consolidated his laboratory with that of Thomas J. Dee & Co., under the direction of James Kilgallon, for the past 20 years chemist with Mr. Dickman.

**Prof. H. M. Parks**, Director of the Oregon Bureau of Mines and Geology, is in eastern Oregon, where he will identify and list the mineral resources of Baker, Grant, and Wallowa counties for the Bureau.

**R. L. Lee** has accepted the position of Assistant Superintendent of the Central Chile Copper Co., Panulcillo, Coquimbo, Chile, and will sail at an early date.

**Elmer A. Holbrook** has been appointed Assistant Professor of Mining Engineering at the University of Illinois, and will have charge of the recently equipped coal-washing and ore-dressing laboratory and the course in mine design.

**J. H. Ivey** is now General Manager of the Poderosa Mining Co., Collalmasi, Chile.

**John T. Fuller** has opened an office in Little Rock, Arkansas, as a mining and civil engineer.

**E. P. Ross**, who was formerly Manager of the Cranberry Furnace Co.'s furnace at Johnson City, Tenn., has accepted a position with the Edgar Thomson Works of the Carnegie Steel Co.

**John C. Branner**, President of Stanford University, has been decorated by the Brazilian Historical and Geographical Society.

**A. J. Eveland** has taken offices at 42 Broadway, New York City.

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## THE INSTITUTE FORUM.

71 BROADWAY, NEW YORK, Sept. 22, 1913.

CHARLES W. GOODALE, *Chairman*,

DARSIE C. BARD, ESQ., *Secretary*.

Committee on Precious and Base Metals,  
Butte, Montana.

Gentlemen:

The wonderful success of the meeting of the Institute held in Montana makes it necessary that some public acknowledgment should be made to those to whom this success is due.

We are conscious that the securing of the great number of technical papers of lasting value and the carrying to success of most complete detailed arrangements for holding the meeting have called for several months of skilled effort on your part.

The benefit of the meeting is very great and extends not only to those who were fortunate enough to be present, but to our four thousand absent members and their friends as well.

To you and your associates on the Committee whose efforts have made this never-to-be-forgotten meeting possible we owe far more than can be expressed in votes of thanks.

Very respectfully,

CHARLES F. RAND, *President*.

## AFFILIATED STUDENT SOCIETIES.

Any society of undergraduates at a technical school, comprising students in any branch of engineering, metallurgy, chemistry, geology, etc., may be recognized by the Board of Directors in its discretion as an Affiliated Student Society. A circular giving details of the plan of affiliation may be obtained on application to the office of the Secretary of the Institute.

The following societies have been placed by authority of the Board of Directors on the above list:

### AFFILIATED STUDENT SOCIETIES.

The Mining Society of the Sheffield Scientific School, Yale University, New Haven, Conn. *President*, Francis S. Winalow; *Secretary*, Roger W. Newberry.

The University of Illinois Student Branch of the American Institute of Mining Engineers, Urbana, Ill. *President*, M. L. Nebel; *Secretary*, Willis Leriche.

The Engineering Society of the University of Nevada, Reno, Nev. *President*, P. E. Raymond; *Secretary*, R. M. Seaton.

The University of Wisconsin Mining Club, Madison, Wis. *President*, Rudolph J. Stengl; *Secretary*, Mack C. Lake.

The Mining and Geological Society of Lehigh University, South Bethlehem, Pa. *President*, Robert C. Mickel; *Secretary*, Edward B. Snyder.

The School of Mines Society of the University of Minnesota, Minneapolis, Minn. *President*, C. A. Walker; *Secretary*, A. C. Bierman.

The Mining Engineering Society of the Massachusetts Institute of Technology. *President*, Ralph E. Wells, Jr.; *Secretary*, Louis W. Currier.

The Student Auxiliary Society of the American Institute of Mining Engineers of the University of Kansas, Lawrence, Kan. *President*, Walter E. Rohrer; *Secretary*, H. R. Brown.

The Associated Miners of the University of Idaho, Moscow, Idaho. *President*, Hallard W. Foester; *Secretary*, Walter P. Scott.

The State College of Washington Mining and Geological Society, Pullman, Wash. *President*, J. V. Quigley; *Secretary*, S. A. Swanson.

The Texas Technical Society, School of Mines, University of Texas, Austin, Tex. *President*, G. C. Cartwright; *Secretary*, David S. Alley.

The Ohio State University Student Branch of the American Institute of Mining Engineers, Columbus, Ohio. *President*, Hugh B. Lee; *Secretary*, E. P. Elliott.

The Stanford Geology and Mining Society, Stanford University, Cal. *President*, B. E. Parsons; *Secretary*, E. D. Nolan.

The Senior Mining Society of Columbia University, New York, N. Y. *President*, Roger L. Strobel; *Secretary*, Clark G. Mitchell.

Mining Association of the University of California, Berkeley, Cal. *President*, D. M. Drumbeller, Jr.; *Secretary*, J. B. Orynaki.

Tufts College Chemical Society, Tufts College, Mass. *President*, F. D. Whittemore; *Secretary*, E. W. Hays.

University of Washington Mining Society, Seattle, Wash. *President*, Oliver P. Searing; *Secretary*, Albert R. Sherman.

Student Branch of the American Institute of Mining Engineers, Iowa State College, Ames, Iowa. *President*, Lyle A. Butler; *Secretary*, A. J. Crawford.

Missouri Mining Association of the Missouri School of Mines, Rolla, Mo. *President*, L. S. Copelin; *Secretary*, L. J. Boucher.

The Pick and Shovel Club of the Case School of Applied Science, Cleveland, Ohio. *President*, M. T. Whelan; *Secretary*, Lloyd A. Collier.

Colorado School of Mines Scientific Society, Golden, Colo. *President*, Alan Kiscock; *Secretary*, George Wilfley.

Mining Engineering Society of the University of Arizona, Tucson, Ariz. *President*, J. Gary Lindley; *Secretary*, H. O. Coles.

Kentucky Mining Society, College of Mines and Metallurgy, University of Kentucky, Lexington, Ky. *President*, Oliver W. Smith; *Secretary*, Charles E. Straub.

Mining Society of Pennsylvania State College, State College, Pa. *President*, Ralph E. Kirk; *Secretary*, Willard M. Lindsey.

**S. F. EMMONS RESEARCH FELLOWSHIP.**

The movement was started by a number of the friends and admirers of the late S. F. Emmons, Economic Geologist of the United States Geological Survey, to perpetuate his name through a fellowship to be known as the "S. F. Emmons Research Fellowship," and they have succeeded in raising some \$13,000 for the purpose of carrying on research work in economic geology.

The Committee in charge of this Memorial Fund has succeeded in obtaining the co-operation of Professors Kemp, of Columbia, Irving, of Yale, and Lindgren, of Massachusetts Institute of Technology, in the administration of this fellowship. These three gentlemen are respectively geologists of the institutions mentioned and are exceptionally qualified to determine in what direction the fund can be best administered. It is hoped that additional contributions will be forthcoming from many who have heard of this movement. Subscriptions are invited and may be sent to any one of these gentlemen, or to Benjamin B. Lawrence, Treasurer, No. 60 Wall Street, New York City.

**BACK VOLUMES OF THE TRANSACTIONS.**

The Board of Directors has authorized the following offers of sets of back volumes of the *Transactions*, at considerably reduced prices, to Members, Libraries, and Scientific Societies:

|                                                                                                                                                                                          | Per Set. |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| I. Five volumes, bound in half-morocco, from No. 36 (1906) to No. 40 (1910),                                                                                                             | \$20     |
| II. Ten volumes, bound in half-morocco, from No. 31 (1902) to No. 40 (1910), including Mexican Volume,                                                                                   | 35       |
| III. Twenty volumes, bound in half-morocco, from No. 21 (1893) to No. 40 (1910),                                                                                                         | 50       |
| IV. Thirty volumes, bound in half-morocco, from No. 11 (1883) to No. 40 (1910),                                                                                                          | 60       |
| V. Thirty-nine volumes, bound in half-morocco, from No. 1 (1873) to No. 40 (1910), with the exception of No. 10 (1882), but including index for Volumes Nos. 1 to 35, and Nos. 36 to 40, | 75       |
| VI. Nine volumes, bound in half-morocco, from No. 1 (1873) to No. 9 (1881),                                                                                                              | 25       |

**INTERNATIONAL ENGINEERING CONGRESS.**

The International Engineering Congress of 1915 will be held under the auspices of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society of Naval Architects and Marine Engineers, and the American Institute of Mining Engineers, in connection with the Panama-Pacific Exposition. Arrangements for this Congress are now proceeding under the General Committee, the Institute representatives on which are given on p. xxxv. An interesting technical program is promised. The time of the Congress is Sept. 20 to 25, 1915. Members of the Institute are cordially invited to attend and participate in the proceedings of the Congress.

## IRON AND STEEL COMMITTEE.

ALBERT SAUVEUR, *Chairman.*A. A. STEVENSON, *Vice-Chairman.*HERBERT M. BOYLSTON, *Secretary, Abbot Bldg., Cambridge, Mass.*

John Birkinbine,  
William H. Blauvelt,  
James Gayley,  
Henry D. Hibbard,  
Henry M. Howe,  
Robert W. Hunt,  
J. E. Johnson, Jr.,

William Kelly,  
Charles Kirchhoff,  
Richard Moldenke,  
Joseph W. Richards,  
C. F. W. Rys,  
E. Gybbon Spilsbury,

J. S. Unger,  
Felix A. Vogel,  
Leonard Waldo,  
William R. Walker,  
William R. Webster,  
Frederick W. Wood.

For the meeting of the Institute which is to be held in New York City, Oct. 16 and 17, 1913, the following program has been arranged:

*October 16, 1913, 10 A. M.*

W. A. Forbes, Blast Furnace Gas Cleaning.  
W. H. Blauvelt, The Slagging Producer.  
Prof. F. Peter (Leoben, Austria), The Generation of Steam by Waste Heat from Furnaces.  
G. C. Stone, The Generation of Steam by Waste Heat from Regenerative Furnaces.  
W. R. Shimer, Over-Oxidation of Steel.

*October 16, 2 P. M.*

Dr. Richard K. Meade, The Use of Powdered Coal as Fuel.  
H. R. Barnhurst, The Use of Powdered Coal as Fuel for Metallurgical Furnaces.  
W. S. Quigley, The Use of Powdered Coal as Fuel.  
E. Stütz, The Scoria Process for the Manufacture of Fine-Ore Briquettes.  
Emile Hiertz, Agglomeration of Flue-Dust by the Chloride of Magnesium Method at the Works of the Societe John Cockerill.  
Felix A. Vogel, The Briquetting of Flue-Dust in the United States.  
R. H. Lee, The Use of Nodulized Ore in the Blast Furnace.  
C. P. Linville, A Chart for Use in Connection with Wet and Dry Bulb Thermometers in Making Pychrometric Determinations.  
P. H. Griffin, The Future of the Chilled Car Wheel.

*October 17, 10 A. M.*

H. M. Howe and A. G. Levy, Determination of the Position of  $A_{e_3}$  in Carbon-Iron Alloys.  
G. K. Burgess, J. J. Crowe, and H. S. Rawdon, Thermal and Microscopical Examination of Professor Howe's Standard Commercial Steels.  
H. M. Howe, Discussion of the Existing Data as to the Position of  $A_{e_3}$ .  
H. M. Howe,  $A_{e_1}$ , The Equilibrium Temperature for  $A_1$  in Carbon Steel.  
G. K. Burgess and J. J. Crowe, The Critical Ranges  $A_2$  and  $A_3$  of Pure Iron.  
W. E. Ruder, Grain Growth in Silicon Steel (if time permits).  
J. H. Hall, Shock Tests of Cast Steel (if time permits).

*October 17, 2 P. M.*

R. R. Abbott, The Influence of Various Elements on the Absorption of Carbon by Steel.  
G. H. Clevenger and B. Ray, The Influence of Copper upon the Physical Properties of Steel.  
J. H. Hall, The Life of Crucible Steel Furnaces.  
H. F. Miller, Jr., New Design of Regenerators for Open-Hearth Furnaces.

*October 17, 1913, 6.30 P. M.*

Subscription Dinner.

HERBERT M. BOYLSTON, *Secretary.*

## COMMITTEE ON INCREASE OF MEMBERSHIP.

ADOLPHE E. BORIE, *Chairman*.THOMAS T. READ, *Secretary*, Woolworth Bldg., New York, N. Y.*Vice-Chairmen.*JOHN H. ALLEN,  
RICHARD M. ATWATER, JR.,  
GEORGE D. BARRON,  
A. CHESTER BEATTY,  
J. PARKE CHANNING,GEORGE M. COLVOCORESSAS,  
ROBERT PEELE,  
CHARLES P. PERIN,  
JOSEPH A. VAN MATER,  
ARTHUR L. WALKER.D. C. Bard,  
W. de L. Benedict,  
John C. Branner,  
Palmer Carter,  
Allan J. Clark,  
C. R. Corning,  
F. Crabtree,  
George G. Crawford,  
O. C. Davidson,  
E. V. D'Inwilliers,  
James S. Douglas,  
Walter Douglas,  
Howard N. Eavenson,  
Howard Eckfeldt,R. C. Gemmell,  
F. Louis Grammer,  
Ernest A. Hersam,  
Edwin C. Holden,  
William L. Honnold,  
Reginald E. Hore,  
Tedaashiro Inouye,  
C. Colcock Jones,  
Eugene P. Kennedy,  
Chester F. Lee,  
Richard S. McCaffery,  
James F. McClelland,  
Milton H. McLean,  
Philip N. Moore,T. H. O'Brien,  
James J. Ormsbee,  
Edward W. Parker,  
John B. Porter,  
F. Danvers Power,  
R. M. Raymond,  
Robert H. Richards,  
LeRoy Salsich,  
Henry Lloyd Smyth,  
F. W. Traphagen,  
Elton W. Walker.  
Cho Yang,  
Morrison B. Young.

A meeting of the Committee on Increase of Membership was held following lunch at the Midday Club, Sept. 19, 1918. Those present were: A. E. Borie, *Chairman*; G. M. Colvocoresses, W. DeL. Benedict, J. H. Van Mater, and Thomas T. Reed.

The Secretary reported that 37 applications for membership were received in July, and 36 in August, although the work of the Committee was necessarily lessened during the summer months. Between Jan. 1 and Sept. 20, 331 applications for membership were received, as compared with 319 for the whole of the preceding year.

Since the last report of the secretary, letters of invitation to send in applications for membership have been sent to the graduates in mining of the University of Toronto, Michigan College of Mines, and Washington State University. Similar letters are being prepared to send to the members of the staff of the Bureau of Mines. In the case of the graduates of the Columbia School of Mines who were similarly invited during June, it was reported that so far as recorded 10 applications have resulted from it. A new field of work which the Committee is following is the sending of invitations to become members to the authors of notable contributions to the leading mining journals. It was further reported that the Committees of the societies which have their headquarters in the Engineering-Societies Building will, at an early date, send a joint letter of invitation to all the members of the Engineers' Club, inviting them to become members of whichever society is of the greatest professional interest to them. At the International Congress of Geology held at Toronto, Aug. 7, to 14, a supply of *Bulletins*, *Year Books*, and applications for membership was provided so that those members of the Institute present at the Congress might have every facility for bringing the Institute to the attention of desirable possible members. At the suggestion of this Committee the President of the Institute sent each foreign member of the Congress a cordial invitation to use the offices of the American Institute of Mining Engineers as a headquarters upon visiting New York City. A number of those present at the Congress have already availed themselves of this invitation.

After some discussion the following resolution was passed:

"Resolved, that this Committee recommend to the Board of Directors that members who have been dropped shall be held eligible for re-election on payment of dues in full to the time at which they were dropped."

After some discussion it was decided that the next meeting should be held at one of the lunch clubs downtown, Oct. 17, and that the Secretary should send out a special letter urging full attendance at the meeting. The meeting then adjourned.

T. T. READ, *Secretary*.



**PUGET SOUND LOCAL SECTION.***Executive Committee.*CHESTER F. LEE, *Chairman.*C. R. CLAGHORN, *Vice-Chairman.*JOSEPH DANIELS, *Secretary-Treasurer,*  
University of Washington, Seattle, Wash.

W. C. BUTLER.

M. K. RODGERS.

On the evening of Tuesday, Sept. 2, an informal dinner was held at the University Club, Seattle, Wash., at which the Secretary of the Institute was present, and a valuable and interesting conference took place concerning the recent activities of the Institute and the relations of the Institute management to the Local Sections.

**SOUTHERN CALIFORNIA LOCAL SECTION.***Executive Committee.*THEODORE B. COMSTOCK, *Chairman.*SEELEY W. MUDD, *Vice-Chairman.*FREDERICK J. H. MERRILL, *Secretary-Treasurer,*  
300 Germain Building, Los Angeles, Cal.

C. COLCOCK JONES.

FRANK ROBBINS.

Maintains headquarters at 300 Germain Building, Los Angeles. Members of the Institute are invited to visit these headquarters whenever they are in the city.

A reception was held at the headquarters of the Section on Wednesday, Sept. 10, at 8 p.m., to meet the Secretary of the Institute and discuss Institute activities and affairs. Light refreshments were served, and about 20 members of the Section attended.

**COLORADO LOCAL SECTION.***Executive Committee.*WILLIAM J. COX, *Chairman.*CHARLES J. MOORE, *Vice-Chairman.*C. LORIMER COLBURN, *Secretary-Treasurer,*  
614 Ideal Building, Denver, Colo.

THOMAS B. STEARNS.

RICHARD A. PARKER.

At the request of a number of members of the Colorado Local Section, President Rand visited Denver on Sept. 2, and addressed a meeting of the members after luncheon at the University Club.

At noon on Tuesday, Sept. 16, a meeting of the Colorado Local Section was held at luncheon at the Hotel Adams, Denver, 25 members being present. The officers whose names are given above were then elected and the Constitution and By-Laws of the Section, which had been already approved by the Board of Directors of the Institute, were adopted. Short informal addresses were made by David W. Brunton, Victor C. Alderson, William J. Cox, Bradley Stoughton, and Seeley W. Mudd, the two latter being the guests of the Section.

**SAN FRANCISCO LOCAL SECTION.***Committee.***S. B. CHRISTY, *Chairman.*****H. FOSTER BAIN,****H. C. HOOVER,****EDWARD H. BENJAMIN,****WILLIAM C. RALSTON,****F. W. BRADLEY.**

A meeting of the Section was held at dinner at the Hotel Bellevue, San Francisco, Cal., on the evening of Friday, Sept. 5, 1913. Prof. Samuel B. Christy presided as Toastmaster, and an informal address was made by the Secretary of the Institute, and short speeches were made by each one of the 12 members present.

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**BOSTON LOCAL SECTION.***Committee.***ROBERT H. RICHARDS, *Chairman.*****ALBERT SAUVEUR, *Vice-Chairman.*****AUGUSTUS H. EUSTIS, *Secretary-Treasurer*, 131 State St., Boston, Mass.****TIMOTHY W. SPRAGUE.****HENRY A. WENTWORTH.**

The thirteenth meeting of the Boston Local Section, preceded by a dinner, was announced to be held at the Engineers' Club, 2 Commonwealth Avenue, Boston, on Monday evening, Oct. 6, 1913, at which Prof. Henry I. Smyth was to speak on The Taxation of Mining Property.

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**ILLINOIS STUDENT BRANCH OF THE INSTITUTE.****M. L. NEBEL, *President.*****WILLIS LERICHE, *Secretary.***

The first meeting of the college year, 1913-1914, was held on Thursday evening, Oct. 2, at the residence of Professor and Mrs. H. H. Stoek. The meeting consisted of a social gathering for the purpose of promoting better acquaintance between the faculty and students of the Department of Mining Engineering.

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**COMMITTEE ON JUNIOR MEMBERS AND AFFILIATED STUDENT SOCIETIES.**

The Board of Directors of the Institute has granted authority to the President to appoint a Committee on Junior Members and Affiliated Student Societies, in order to promote this phase of the Institute's activities, and especially to bring about a closer relationship between the student societies and junior members and the members and management of the Institute.

## LIBRARY.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

AMERICAN INSTITUTE OF MINING ENGINEERS.

UNITED ENGINEERING SOCIETY.

WILLIAM P. CUTTER, Librarian.

The Library of the above-named Societies is open from 9 A.M. to 9 P.M. on all week-days, except holidays, from September 1 to June 30, and from 9 A.M. to 6 P.M. during July and August. The Library contains about 55,000 volumes, including sets of technical periodicals and the publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library can render valuable service through correspondence; letters requesting information will receive special attention. The Library is prepared to furnish references and copies of articles on mining and metallurgical subjects; to determine the existence of mining-maps, and to furnish general information as to the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

The members of the Institute can be of service to the Library by forwarding copies of mining-reports, maps privately issued, and similar material, which will be classified, indexed, and made available to other members. Suggestions for additions to the Library, either by purchase or personal solicitation as gifts, will be welcomed. It is hoped that members while in the city will use the Library freely, and assurance is given that most careful service will be rendered to them.

## Library Accessions.

Aug. 16 to Sept. 30, 1913.

AMERICAN INSTITUTE OF METALS. Transactions, Vol. VI. Buffalo, 1913. (Exchange.)

ANNALES DES MINES. Table des Matières, 1902-1911. Paris, 1913. (Gift of Dunod et Pinat.)

OUR ARTESIAN WATERS. Observations in the Laboratory and in the Field. By R. S. Symmonds. Sydney, 1912. (Gift of Author.)

BELGIUM. MINISTÈRE DE L'INTERIEUR. Annuaire Statistique de la Belgique, 1912. Bruxelles, 1913. (Gift of Ministère de l'Interieur.)

BIBLIOGRAPHIE DER DEUTSCHEN ZEITSCHRIFTEN LITERATUR. Band XXXI., 1912. By F. Dietrich. Leipzig, 1913. (Purchase.)

BIBLIOGRAPHIE DER FREMDSPRACHIGEN ZEITSCHRIFTENLITERATUR. Bd. V. By F. Dietrich. Leipzig, 1913. (Purchase.)

BIBLIOGRAPHY OF WASHINGTON GEOLOGY AND GEOGRAPHY. (Bulletin No. 12, Washington Geological Survey.) Olympia, 1913. (Exchange.)

BOSTON SOCIETY OF CIVIL ENGINEERS. Year Book, 1913-14. Boston, 1913. (Exchange.)

BROKEN HILL PROPRIETARY CO. Reports and Statements of Account for half-year ending May 31, 1913. Victoria, 1913. (Gift of Broken Hill Proprietary Co.)

BROKEN HILL SOUTH SILVER MINING CO. Reports, Statements of Accounts, etc., for half-year ended June 30, 1913. Melbourne, 1913. (Gift of W. E. Wainwright.)

BROOKLYN ENGINEERS' CLUB. Proceedings, 1912. Brooklyn, 1913. (Gift of Club.)

- CEMENT RESOURCES OF THE BLACK HILLS.** (Bulletin No. 8, South Dakota School of Mines.) Rapid City, 1908. (Exchange.)
- COAL RESOURCES OF THE WORLD.** Vols. 1-3, with Atlas. An inquiry made upon the initiative of the Executive Committee of the XII. International Geological Congress, Canada, 1913. Toronto, Morang & Co., Ltd., 1913. Price, \$25 per set net. (Gift of Publishers.)
- COMITE DES FORGES DE FRANCE.** Annuaire, 1913-14. Paris, 1913. (Exchange.)
- CONTRIBUTIONS TO SCIENTIFIC AND TECHNICAL PUBLICATIONS.** 1883-1913. By W. B. Phillips. N. p., n. d. (Gift of Author.)
- ECONOMIC MINERALS AND MINING INDUSTRIES OF CANADA.** Ottawa, 1913. (Exchange.)
- ENGINEERING STANDARDS COMMITTEE.** British Standard Screwing for Marine Boiler Stays. (No. 62.) August, 1913. Westminster, 1913.
- British Standard Specifications for Cold Drawn Weldless Steel Tubes for Locomotive Boilers. (No. 53, revised.) August, 1913. London, 1913.
- British Standard Specification for Sizes of Broken Stone and Chippings. (No. 63.) London, 1913.
- British Standard Specification for Steel Fishbolts and Nuts for Railway Rails. (No. 64.) London, 1913.
- British Standard Specification for Wrought Iron for use in Railway Rolling Stock. (No. 51, revised.) London, 1913. (Gift of Engineering Standards Committee.)
- ENGINEERS' CLUB OF PHILADELPHIA.** Directory, 1913. Philadelphia, 1913. (Exchange.)
- FABRICATION DE L'ACIER.** Ed. 10. By H. Noble. Paris, 1913. (Purchase.)
- FINANCIAL AND ECONOMIC ANNUAL OF JAPAN.** 13th, 1913. Tokyo, 1913. (Gift of Department of Finance of Japan.)
- GENERAL METALLURGY.** By H. O. Hofman. New York, McGraw-Hill Book Co., 1913. Price \$5 net. (Gift of Publishers.)

[NOTE.—It is many years since Professor Hofman, before taking his place in the faculty of the "Tech," made himself known to the metallurgical public as a singularly close observer, keen investigator and comprehensive reporter of practice and progress in that sphere. The monographs and books which he has already published, as well as the students whom he has trained, bear witness to his competency as author, teacher and critic; and it is matter for general congratulation that he is preparing a series of metallurgical treatises, of which the present volume is the first. The others, which will be issued at brief intervals, will deal with copper, iron and steel, lead and the minor metals.

Under the head of general metallurgy, the book before us treats of the properties of metals and alloys; metallic compounds and ores; fuel; refractory materials; pyrometallurgical, hydrometallurgical and electrometallurgical processes and apparatus; the operations of mechanical metallurgy (including the crushing, dressing and briquetting of ores, the forging, rolling and drawing of metals and alloys, the pumping, piping and filtering of liquids, and the conduction, compression, preheating, dessication and purification of air and gases); metallurgical products; and economic considerations. In all these departments, the clear and comprehensive text is enriched with numerous illustrations and copious references to modern technical literature. In his preface, the author gives discriminating credit to the general treatises of Grüner, Kerl, Schnabel and others, but shows conclusively that no one of them satisfactorily covers the ground. In short he demonstrates that there was a place for his work, and the work itself fills that place well.—R. W. R.]

- GEOLOGIC RECONNAISSANCE OF THE FAIRBANKS QUADRANGLE, ALASKA.** (Bulletin No. 525, U. S. Geological Survey.) Washington, 1913. (Exchange.)
- GEOLOGY AND ORE DEPOSITS OF LEMHI COUNTY, IDAHO.** Bulletin No. 528, U. S. Geological Survey. Washington, 1913. (Exchange.)
- GEOLOGY AND ORE DEPOSITS OF THE COVADA MINING DISTRICT.** (Bulletin No. 16, Washington Geological Survey.) Olympia, 1913. (Exchange.)
- GEOLOGY AND ORE DEPOSITS OF THE SAN FRANCISCO AND ADJACENT DISTRICTS, UTAH.** (Professional Paper No. 80, U. S. Geological Survey.) Washington, 1913. (Exchange.)
- GEOLOGY OF THE NOME AND GRAND CENTRAL QUADRANGLES, ALASKA.** (Bulletin No. 533, U. S. Geological Survey.) Washington, 1913. (Exchange.)
- HANDBUCH DER MINERALCHEMIE.** Band II, pt. 3. By C. Doelter. Dresden-Leipzig, 1913. (Purchase.)
- IGNEOUS ROCKS.** Vol. 2. By J. P. Iddings. New York, 1913. Price, \$6 net. (Gift of John Wiley & Sons.)

[NOTE.—In the *Bulletin* for September, 1909, I expressed my admiration of the first volume of this treatise. The second volume, dealing with the description and occurrence of the igneous rocks, is worthy of equal praise. No other department of geology has received greater illumination through the modern means of laboratory research and field examination. Mr. Iddings has collected from an abundant, though scattered, literature, and from his own original work, ample material for a comprehensive and systematic account. As he frankly confesses in his preface, the great difficulty in using this material has been its heterogeneity in respect of the method of observation and the nomenclature of records. Coming from different observers, the same names of classes or species do not always mean the same things. But Mr. Iddings has met this difficulty with noteworthy skill, so that his book presents a practically trustworthy summary of the classification and distribution of the igneous rocks of a large part of the earth's surface. Forty years ago, in addressing an international meeting of geologists at the Vienna Exposition of 1873, I made bold to say that the North American continent would supply the material for a new chapter in geology, whenever the record of its igneous rocks should be deciphered. This vague prophecy, based upon my own superficial reconnaissance of a large part of the Pacific slope, has received overwhelming fulfillment through the work of American geological explorers and students, from Richthofen down through a long and illustrious list. Mr. Iddings's admirable discussion of North America and contiguous islands furnishes much more than the chapter of which I then dreamed; and his book as a whole, with its fine generalizations, clear descriptions, and almost innumerable tabulated analyses, is a book which Americans will receive with pride, and all the world with praise and thanks.—R. W. R.]

INTERNATIONAL RAILWAY FUEL ASSOCIATION. Proceedings of the Fifth Annual Convention. N. p., n. d. (Gift of International Railway Association.)

INTRODUCTION TO THE STUDY OF IGNEOUS ROCKS. By G. I. Finlay. New York, McGraw-Hill Book Co., 1913. (Purchase.)

INVESTIGATION OF DETONATORS AND ELECTRIC DETONATORS. (Bulletin No. 59, U. S. Bureau of Mines.) Washington, 1913. (Exchange.)

IRON AND STEEL INSTITUTE. Journal, vol. 87, 1913, No. 1. London, 1913. (Exchange.)

JAHRBUCH DER ELEKTROCHEMIE. Jahrgang XV, 1. Hälfte. Halle, 1913. (Purchase.)

JOHN CRERAR LIBRARY. List of Current Medical Periodicals and Allied Serials. Ed. 2, April, 1913. Chicago, 1913. (Exchange.)

KÖNIGLICHEN BERGAKADEMIE ZU CLAUSTHAL. Chronik, 1912-13. Clausthal, 1913. (Exchange.)

— verzeichnis der Vorlesungen, 1913-14. Clausthal, 1913. (Exchange.)

KONIGL. SACHS. BERGAKADEMIE ZU FREIBERG. Programm, 1913-14. Freiberg, 1913. (Exchange.)

DIE LAGERSTÄTTEN DER NUTZBAREN MINERALIEN UND GESTEINE NACH FORM, INHALT UND ENTSTEHUNG. Drei Bände. II Band. By F. Beyschlag, P. Krusch and J. H. L. Vogt. Stuttgart, 1913. (Purchase.)

METAL INDUSTRY. Vols. 1-4. London, 1909-12. (Purchase.)

METALLBANK UND METALLURGISCHE GESELLSCHAFT. Comparative Statistics of Lead, Copper, Spelter, Tin, Aluminium, Nickel, Quicksilver and Silver. 19th annual issue, 1903-1912. Frankfurt on Main, 1913. (Gift of Metallbank und Metallurgische Gesellschaft.)

MICHIGAN COLLEGE OF MINES. Year Book, 1912-13. Houghton, 1913. (Exchange.)

MISSISSIPPI STATE GEOLOGICAL SURVEY. Bulletin No. 10. Jackson, 1913. (Exchange.)

MITTEILUNGEN AUS DEM EISENHÜTTENMÄNNISCHEN INSTITUT DER KÖNIGL. TECHN. HOCHSCHULE AACHEN. Band V. By F. Wüst. Halle, 1913. (Purchase.)

NEW SOUTH WALES. DEPARTMENT OF MINES. Mineral Resources. No. 7. Sydney, 1913. (Exchange.)

NOVA SCOTIA. DEPARTMENT OF MINES. Report, 1912. Halifax, 1912. (Exchange.)

OHIO. GEOLOGICAL SURVEY. Bulletin No. 17 (4th ser.). Columbus, 1912. (Exchange.)

ONTARIO. BUREAU OF MINES. Report, vol. 19, pt. 11. Toronto, 1913. (Gift of Bureau of Mines of Ontario.)

ORIENTAL CONSOLIDATED MINING CO. Report for the year ending June 30, 1913. New York, 1913. (Gift of Oriental Consolidated Mining Co.)

PETROLEUM. Ed. 3, vols. 1-3. By Boverton Redwood. London, 1913. (Purchase.)

PHILADELPHIA MUSEUM (COMMERCIAL). Annual Report, 1912. Philadelphia, 1912. (Exchange.)

PREVENTION OF WASTE OF OIL AND GAS FROM FLOWING WELLS IN CALIFORNIA. (Technical Paper No. 42, U. S. Bureau of Mines.) Washington, 1913. (Exchange.)

PRINCETON ENGINEERING ASSOCIATION. Report and List of Members, 1913-14. New Jersey, 1913. (Gift of Association.)

RAND METALLURGICAL PRACTICE. Vol. 2. London, 1912. (Gift of W. A. Caldecott and W. R. Dowling.)

[NOTE.—The first volume of this work was noticed in *Bulletin* No. 68 (August, 1912), and what was there said of the undertaking as a whole need not be repeated here. That volume was produced by several leading practitioners on the Rand, each treating a separate subject. This one, dealing with the design and construction of plants, and the transportation of materials, is the work of a single author, Mr. C. O. Schott, member of the Institution of Mining and Metallurgy, and of the South African Institution of Engineers. It presents a clear and comprehensive statement, accompanied by 434 illustrations, of the practice on the Rand.—R. W. R.]

SOUTH DAKOTA SCHOOL OF MINES. Bulletin No. 8. Rapid City, 1908. (Exchange.)

SUL MODO DI FORMAZIONE DEI PRINCIPALI GIACIMENTI METALLIFERI AVENTI FORMA DI IRREGOLARI AMMASSI O DI STRATI. By P. Toso. Roma, 1913. (Gift of Author.)

SULLA GENESI DEI GIACIMENTI SOLFIFERI DI SICILIA. By P. Toso. Roma, 1913. (Gift of Author.)

SVENSKA TEKNOLOGFÖRENINGEN. Ledamotsförteckning. Juli, 1913. Stockholm, 1913. (Exchange.)

TASMANIA. SECRETARY FOR MINES. Report, 1912. Tasmania, 1913. (Exchange.)

TREATISE ON GENERAL AND INDUSTRIAL ORGANIC CHEMISTRY. By Ettore Molinari. Translated from the second enlarged and revised Italian edition by T. H. Pope. Philadelphia, P. Blakiston's Sons & Co., 1913. Price \$6. (Gift of Publishers.)

[NOTE.—Dr. Molinari is Professor of Industrial Chemistry to a technical society in Milan, and of Muceology at the Luigi Bocconi Commercial University in the same city. His book on General and Industrial Chemistry (noticed in the *Bulletin* of December last) was translated by Dr. Ernest Feilman, of London. Mr. Pope, the translator of the present work, is an instructor in the School of Malting and Brewing of the University of Birmingham, and his translation constitutes practically a third edition, since the author himself has contributed new material to it—chiefly additional statistics for Great Britain and the United States.

What I said of the former treatise may be said with equal truth of this. It is a wonderfully clear, compact, and comprehensive account of modern organic chemistry, both in theory and in industrial application. The introduction of the latter element gives to it a fascination and interest not to be expected in a purely abstract discussion.

Part I. deals with the general aspects of the subject, such as the purification, analysis, empirical formulæ, properties, classification, and nomenclature of organic compounds. Part II. discusses the derivatives of methane (hydrocarbons and their halogen derivatives, alcohols and their derivatives, acids and their derivatives, and aldehydic alcohols). Part III. is devoted to cyclic compounds (cycloparaffins and benzene derivatives or aromatic compounds—the latter title covering a long list of perfumes and dyes—and textile fibers, proteins, glucosides, etc.). At every step industrial applications and processes are collaterally described, so that the book becomes a cyclopedia. For interesting specimens of this method, the reader may be referred to the sections on the origin of petroleum, the manufacture of soap, the theory and practice of dyeing, and to many others, equally up-to-date. Like the treatise on inorganic chemistry, above mentioned, it is the equivalent of two volumes. Its 769 pages of small but clean and clear type with more than 500 "inset" illustrations present an amazing amount of logically arranged and thoroughly indexed information. The success of the author's method is the more conspicuous in this case, as the subject of organic is more complicated and difficult to handle than that of inorganic chemistry.—R. W. R.]

UNION OF SOUTH AFRICA. MINES DEPARTMENT. Annual Report, 1912, pt. 1-2. Pretoria, 1913. (Gift of South Africa Mines Department.)

U. S. BUREAU OF MINES. Bulletin Nos. 59, 61. Washington, 1913. (Exchange.)

— Technical Papers Nos. 42, 47. Washington, 1913. (Exchange.)

U. S. COAST AND GEODETIC SURVEY. Results of observations made at the United States Coast and Geodetic Survey magnetic observatory at Cheltenham, Maryland, 1911 and 1912. Washington, 1913. (Exchange.)

- U. S. GEOLOGICAL SURVEY. Bulletin Nos. 525, 528, 533. Washington, 1913. (Exchange.)  
 — Professional Paper Nos. 80, 85-A. Washington, 1913. (Exchange.)  
 U. S. INTERSTATE COMMERCE COMMISSION. Bulletin of revenues and expenses of steam roads in the United States, No. 54, May, 1913. Washington, 1913. (Gift of Commission.)  
 U. S. NATIONAL MUSEUM. Proceedings. Vol. 44. Washington, 1913. (Exchange.)  
 — Report on the Progress and Condition of the United States Museum for the year ending June 30, 1912. Washington, 1913. (Exchange.)  
 WASHINGTON GEOLOGICAL SURVEY. Bulletin Nos. 12, 16. Olympia, 1913. (Exchange.)  
 WEST OF SCOTLAND IRON AND STEEL INSTITUTE. List of members, 1912-13. Glasgow, 1913. (Exchange.)  
 WESTERN AUSTRALIA. DEPARTMENT OF MINES. Report, 1912. Perth, 1913. (Exchange.)  
 YALE UNIVERSITY. Report of the President, 1912-13. New Haven, 1913. (Exchange.)

TECHNISCHEN HOCHSCHULE FRIDERICIANA ZU KARLSRUHE.

- BÜRGIN, J. Genauigkeitsuntersuchungen über die Bestimmung der Intensität der Schwerkraft durch relative pendelmessungen. Karlsruhe, 1912.  
 CARTER, F. E. Ueber die Verbrennung von Wasserstoff mit Sauerstoff. München, 1912.  
 CZAKÓ, EMERICH Beiträge zur Kenntnis natürlicher Gasausströmungen. Karlsruhe, 1913.  
 FAJANS, KASAMIR. Die verzweigung der Radiumzerfallsreihe. Heidelberg, 1912.  
 JOYNER, R. A. Katalyse von Camphocarbonsäure durch Basen in verschiedenen Lösungsmitteln. Karlsruhe, 1913.  
 KARLSRUHE TECHNISCHE HOCHSCHULE. Programm, 1913-14. Karlsruhe, 1913.  
 MASCHKO, ALFRED. Neubestimmung des Ammoniakgleichgewichtes bei gewöhnlichem Druck. Karlsruhe, 1913.  
 PLIENINGER, REGINALD. Untersuchungen über das Verfahren: Eisen mittels des Sauerstoffstrahles zu durchtrennen (autogenes schneidverfahren). Zurich, 1912.  
 SCHLUMBERGER, ERNST. Ueber die statische Bestimmung des Ammoniakgleichgewichtes in der Nähe von 500° C. Karlsruhe, 1912.  
 SCHUMANN, W. O. Über die Drehmomente der Dämpferwicklung einer Mehrphasen Synchronmaschine bei kleinen Pendelschwingungen im Parallelbetrieb. Karlsruhe, 1912.  
 SCHWAIGER, A. Belastungsausgleich in Kraftwerken. Berlin, 1912.  
 SEGER, WALTER. Ueber die Verwendung australischer Schiefer zur Gaserzeugung. Karlsruhe, 1913.  
 WEISSMANN, LEON. Ueber die Abgabe von elektrisch geladenen Teilchen durch einen glühenden Platindraht während der Katalyse von Knallgas. Leipzig, 1912.  
 WIRZ, EMIL. Beitrag zur Theorie und Untersuchung der Ferrarismessgeräte. Berlin, 1912.

GIFT OF HILL PUBLISHING CO.

- BRANDEIS, GOLDSCHMIDT & Co. Annual Report, 1910.  
 CANADA. CUSTOMS DEPARTMENT. Trade and Navigation unrevised monthly statements of imports entered for consumption. May, 1913.  
 FEDERAL MINING & SMELTING Co. Annual Report for the fiscal year ending Aug. 31, 1911.  
 MARYLAND. CONSERVATION COMMISSION. Report, 1908-09.  
 MOUNT MORGAN GOLD MINING Co., LTD. Reports and statements of accounts for year ended May 31, 1913.  
 NATIONAL LEAD Co. Report, 1907, 1910.  
 OBERSCHLESISCHEN BERG UND HÜTTENMANNISCHEN VEREINS. Bericht, 1912-13.  
 PANAMA PACIFIC INTERNATIONAL EXPOSITION. Universal Exposition, 1915. Rules and regulations,  
 UNITED STATES SMELTING, REFINING & MINING Co. Annual Report, 7th, 1912.

## TRADE CATALOGUES.

- ABENAGUE MACHINE WORKS. Boston, Mass. Portable air compressors. 36 pp.
- ASBESTOS PROTECTED METAL CO., Beaver Falls, Pa. Bulletin No. 53. Asbestos steel for roofs and walls.
- CHICAGO PNEUMATIC TOOL CO., Chicago, Ill. Bulletin No. 148. Hand drills and portable compressors. Sept., 1913.
- BULL. E-29. Duntley Electric Grinders. Aug. 1, 1913.
- BULL. 34 B. "Chicago Pneumatic" Power-driven Compressors. May, 1912.
- DE LA VERGNE MACHINE CO., New York, N. Y. Bulletin No. 132. "De La Vergne" oil engine Type "FH."
- HENDRYX CYANIDE MACHINERY CO., New York, N. Y. Catalogue No. 8. Hendryx agitator.
- HOYT METAL CO., St. Louis, Mo. Catalogue of articles manufactured. 1913.
- LESCHEN, A. & SONS ROPE CO., St. Louis, Mo. Leschen's Hercules. Sept., 1913.
- MCCORD MANUFACTURING CO., Detroit, Mich. Form 129 A. Class "B" force-feed lubricator.
- MERRILL METALLURGICAL CO., San Francisco, Cal. Merrill Zinc Dust (or Powder) Precipitation Process.
- Merrill automatic sluicing pressure slime filter.
- Merrill sluicing clarifying filter.
- SANFORD-DAY IRON WORKS, Knoxville, Tenn. Wheelology. Aug., 1913.
- WHEELING CORRUGATING CO., Wheeling, W. Va. Butt-joint nestable corrugated metal culvert.

## United Engineering Society Library.

- FIRE TESTS OF FLOORS IN THE UNITED STATES. (International Association for Testing Materials, Vith Congress, New York.) By I. H. Woolson. New York, 1912. (Gift of I. H. Woolson.)
- INTERNATIONALEN KÄLTEKONGRESS (DRITTE). Festschrift, Washington-Chicago, Sept. 15-24, 1913. Berlin, 1913. (Gift of Internationalen Kältenkongress.)
- NEW YORK TIMES INDEX. January-June (2 vols.). New York, 1913. (Purchase.)
- LES NOUVEAUX SCIENTIFIQUES ET INDUSTRIELS. Vols. 1-2, 1902-12. Paris, 1908-1913. (Purchase.)
- OHIO. PUBLIC SERVICE COMMISSION. Report, 1912. Springfield, 1913.
- A compilation of the laws of Ohio affecting the Regulation of Railroads and Public Utilities, 1913. Columbus, 1913.
- An Act to create the Public Utilities Commission of Ohio, to prescribe its organization, etc. N. p., 1913. (Gift of Ohio Public Service Commission.)
- PROGRESS OF GERMAN SHIPBUILDING, with special reference to the evolution of the fleet of the Norddeutscher Lloyd. (English-German.) Berlin, 1909. (Gift of North German Lloyd Steamship Co.)
- THIRTY YEARS OF NEW YORK, 1882-1912, being a history of electrical development in Manhattan and the Bronx. New York, Press of the New York Edison Co., 1913. (Gift of New York Edison Co.)

This is an extremely interesting volume, giving not only a history of the company, showing its marvelous growth, but containing much matter relating to old-time New York, the New York of the horse car, the gas light, and the elevator building; a city without electric cars or telephone. The work is profusely illustrated, having many reproductions of sketches by Joseph Pennell, Vernon Howe Bailey, and others.

A comparatively small edition was printed. This is regrettable, for the book deserves a wide circulation. This is one of two books in the Library which the Librarian has read through.—W. P. C.

TROW'S GENERAL DIRECTORY OF THE BOROUGHES OF MANHATTAN AND BRONX, CITY OF NEW YORK. Vol. 127, 1913. (Purchase.)



## MEMBERSHIP.

## NEW MEMBERS.

The following list comprises the names of those persons who became members during the month of September, 1913:

*Members.*

|                                                                                                                                  |                                          |
|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| ANDERSON, ANDREW P., Min. Engr.....                                                                                              | 908 Story Bldg., Los Angeles, Cal.       |
| ANDROS, STEPHEN O., Min. Engr.....                                                                                               | University of Illinois, Urbana, Ill.     |
| BECKETT, PERCY G., Min. Engr.....                                                                                                | Globe, Ariz.                             |
| BLAIR, THOMAS S., JR., Prest. Blair Engrg. Co.....                                                                               | 343 S. Dearborn St., Chicago, Ill.       |
| BOYLE, HARRY, Min. Engr.....                                                                                                     | 807 Lowman Bldg., Seattle, Wash.         |
| BRADEN, EUGENE B., Vice-Prest., Selby Smelting & Lead Co.,<br>Merchants Exchange Bldg., San Francisco, Cal.                      |                                          |
| CHALMERS, JOHN W., Min. and Elec. Engr., Morro Velho, Villa Nova de Lima,<br>Honorio Becalho, Minas Geraes, Brazil, So. America. |                                          |
| COMINS, WALDO H., Supt., St. Louis Smelting & Refining Co.....                                                                   | St. Francois, Mo.                        |
| DODGE, CLEVELAND E., Mining.....                                                                                                 | 90 Park Ave., New York, N. Y.            |
| DUNN, EDGAR M., Metallurgical Chemist.....                                                                                       | P. O. Box 335, Anaconda, Mont.           |
| ELSING, MORRIS J., Min. Engr. and Geol., Cananea Cons. Copper Co., Cananea, Son., Mexico.                                        |                                          |
| ELTON, JAMES O., Met. Engr.....                                                                                                  | 611 Maple Street, Anaconda, Mont.        |
| ENGELHARDT, EUGENE N., Supt., Selby Smelting & Lead Co., 647 El Dorado Ave.,<br>Oakland, Cal.                                    |                                          |
| EVANS, DAVID J., Smelter Supt., Cons. Arizona Smelting Co.....                                                                   | Humboldt, Ariz.                          |
| GREBE, EMIL, Min. Engr.....                                                                                                      | Warren, Ariz.                            |
| HACKWOOD, ARTHUR W., Mill Supt., North American Smelting Co.,<br>Perth Road, Ont., Canada.                                       |                                          |
| HAMILTON, HARRY F., Mining.....                                                                                                  | Bisbee, Ariz.                            |
| HAMMOND, LYMAN P., Vice-Prest. and Genl. Mgr., Colorado Power Co.,<br>Symes Bldg., Denver, Colo.                                 |                                          |
| HAWLEY, ROBERT H., Asst. Supt., Magna Plant, Utah Copper Co.....                                                                 | Garfield, Utah.                          |
| HAYES, FRANCIS H., Geol.....                                                                                                     | P. O. Box 267, Morenci, Ariz.            |
| HENDERSON, ROBERT M., Mgr., Wellington Mines Co.....                                                                             | Breckenridge, Colo.                      |
| HENRY, WILBUR E., Ore Dept., New Jersey Zinc Co.....                                                                             | 55 Wall St., New York, N. Y.             |
| HESS, EDWIN W., Cons. Engr.....                                                                                                  | Kratzer Bldg., Clearfield, Pa.           |
| HESS, RUSH MINER, Min. Engr., South American Mines Co.,<br>P. O. Box 655, Guayaquil, Ecuador, So. America.                       |                                          |
| HINCKLEY, ELMER R., Mine Supt., Chosen Mining Co.....                                                                            | Seoul, Korea.                            |
| JACKSON, GEORGE T., Min. Engr., Alaska-Gastineau Mining Co.....                                                                  | Juneau, Alaska.                          |
| JACKSON, WALTER S., Min. Engr.....                                                                                               | P. O. Box 283, Morenci, Ariz.            |
| KAMMERER, CHARLES, Mgr., Conrey Placer Co.....                                                                                   | Ruby, Mont.                              |
| LONDON, STEPHEN L., Mine Supt.....                                                                                               | Fierro, N. M.                            |
| LEONARD, WILLIAM H., Denver Rock Drill Mfg. Co., 18th & Blake Sts., Denver, Colo.                                                |                                          |
| LOUGHBRIDGE, CHARLES.....                                                                                                        | 901 Foster Bldg., Denver, Colo.          |
| MCBROKEN, EUGENE P., Min. Engr.....                                                                                              | 135 W. 92d St., New York, N. Y.          |
| MCLEAN, FRANK W., Asst. Mine Supt., Detroit Copper Mining Co. of Ariz., Morenci, Ariz.                                           |                                          |
| MEER, HARRY C., Mine Supt., Dome Mines Co., Ltd.....                                                                             | South Porcupine, Ont., Canada.           |
| MOORE, CARL F., Cons. Engr., U. S. Smelting, Refining & Mining Co.,<br>920 Newhouse Bldg., Salt Lake City, Utah.                 |                                          |
| PAUL, RUSSELL B., Min. Engr.....                                                                                                 | 703 Symes Bldg., Denver, Colo.           |
| PERSSING, PROCTOR O., Asst. Supt., Spanish-American Iron Co.....                                                                 | Daiquiri, Cuba.                          |
| REIFENBERGER, LE BARON B., Mine Supt., Spanish-American Iron Co.....                                                             | Daiquiri, Cuba.                          |
| RIBALKIN, MICHAEL P., Prof. of Met., Vassilevsky Ostrov., No. 17 on 11,<br>St. Petersburg, Russia.                               |                                          |
| RICHARDS, WILLIAM J., Supt. of Mines .....                                                                                       | Crystal Falls, Mich.                     |
| ROBINSON, BURR A., Asst. to Secty., Am. Institute of Mining Engineers,<br>29 West 39th St., New York, N. Y.                      |                                          |
| RODGERS, SELDEN S., Foreman, McDougall Furnace Dept., Anaconda Copper Mining Co.,<br>Great Falls, Mont.                          |                                          |
| RUBIDGE, FREDERICK T., Min. Engr.....                                                                                            | 41 Broad Street, New York, N. Y.         |
| SALE, ANDREW J., Min. Engr., Giroux Cons. Mines Co.....                                                                          | Kimberly, Nev.                           |
| SAWYER, EUGENE W., Mine Supt.....                                                                                                | Tyrone, N. M.                            |
| SCOTT, WILLIAM G., Mine Supt.....                                                                                                | P. O. Box 254, Morenci, Ariz.            |
| SEIP, ROBERT H., Min. Engr.....                                                                                                  | P. O. Box 279, Jenkins, Letcher Co., Ky. |
| SHROOP, WALTER M., Asst. to Supt., Spanish-American Iron Co., Felton, Oriente, Cuba.                                             |                                          |
| SHUMWAY, RALPH W., Chief Engr., Rocky Mountain Fuel Co., 1102 Foster Bldg.,<br>Denver, Colo.                                     |                                          |

STAPLES, CHARRON M., Min. Engr.....P. O. Box 744, Morenci, Ariz.  
 THOMSON, ALEXANDER F., Genl. Mgr., Detroit Copper Mining Co.....Morenci, Ariz.  
 TYEMANN, HUGH P., Met.....Carnegie Steel Co., Pittsburg, Pa.  
 WEIGEL, WILLIAM M., Min. Engr.....108 Earl St., Kingston, Ont., Canada  
 WHITNALL, HAROLD O., Geol.....Hamilton, N. Y.  
 WRIGHT, GEORGE A., Engineer, Spanish-American Iron Co.....Felton, Oriente, Cuba.

#### *Associates.*

ANDERSON, ALBERT H., Abrasive Mill Foreman.....22 Barber Ave., Worcester, Mass.  
 MUNOZ, PAUL J., Min. and Mech. Engr.....929 Central Bldg., Los Angeles, Cal.  
 STEWART, JUDD, Director, Am. Smelting & Refining Co., 165 Broadway, New York, N. Y.

#### *Junior Members.*

BLACK, FREDERICK C., Millman.....Wonder, Nev.  
 DODGE, WILLIAM E., Student.....415 W. Highland Ave., Shawnee, Okla.  
 GATCH, NELSON B., Min. Engr.....5266 Westminster Pl., St. Louis, Mo.  
 HYDE, REED W., Chem., Am. Smelting & Refining Co.....Murray, Utah.  
 LAMB, HERBERT W., Min. Engr.....45 Toledo St., Adrian, Mich.  
 LEACH, ROY, Cyaniding.....Melones, Calaveras Co., Cal.  
 PIERSE, EDWIN A., Min. Engr., Butte & Great Falls Mining Co.....Great Falls, Mont.  
 PRICE, JOHN M., Min. Engr.....Montreal, Wis.

#### CANDIDATES FOR MEMBERSHIP.

The following persons have been proposed during the month of September, 1913, for election as members of the Institute. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

#### *Members.*

**Charles Walter Adams, Jr., Murray, Utah.**

Proposed by C. W. Whitley, J. B. McIntosh, B. N. Rickard.

Born, 1888, Mitchell, S. D. 1906 Grad., Mitchell High School. 1907, Dakota Wesleyan, business course. 1909, South Dakota School of Mines. 1910, Missouri School of Mines. 1911, Utah School of Mines, B. S. 1905, Asst. Chemist, Turner Produce Co. 1907, Surveying. C. M. & St. P. R. R. 1908, summer, Homestake Mine, Lead, S. D. 1909, summer, U. S. Mine, Bingham, Utah. 1910, summer, Millman, Lundberg Door Wilson Cyanide Plant. 1911-12, Asst. Western Contracting Engr., Midland Bridge Co., Kansas City, Mo.

Present position: 1912 to date, Metallurgist, Operating Dept., American Smelting & Refining Co., Lead Plant.

**Frank H. Armstrong, Vulcan, Mich**

Proposed by William Kelly, O. C. Davidson, C. H. Baxter.

Born, 1877, Serena, Ill. 1899, Graduate of Mechanical Engineering Department of University of Illinois. 1899-01, Asst. M. M., Cleveland-Cliffs Iron Co., Ishpeming, Mich. 1901-02, M. M., Crystal Falls Iron Mining Co., Crystal Falls, Mich. 1902-04, M. M., Republic Iron Co., Republic, Mich.

Present position: 1904 to date, Mechanical Engineer, Penn Iron Mining Co. and Republic Iron Co.

**Harold Purdy Banks, New York, N. Y.**

Proposed by Arthur L. Walker, E. J. Hall, John H. Banks.

Born, 1887, New York, N. Y. 1904-08, Columbia College (A. B., 1910). 1908-11, Columbia School of Mines; E. M. 1909, Engineer, Copper Queen Cons. Min. Co. 1911-12, Engineer, sampler and mill operator, Miami Copper Co.

Present position: 1912 to date, Asst. in Metallurgy, School of Mines, Columbia Univ.

**Lionel Brooke**, Golden, Colo.

Proposed by William R. Hedsey, Harry J. Wolf, F. W. Traphagen.

Born, 1888, Daggett, Cal. 1908, Graduate Los Angeles Polytechnic High School. 1908-11, Colorado School of Mines. Two years with New York & Honduras Rosario Mining Co., on engineering staff and various positions up to that of Asst. Supt. of Reduction Works.

Present position : Senior Student Colorado School of Mines for E. M. degree.

**John Lorraine Cavanagh**, Wabana, Newfoundland.

Proposed by George B. McCunn.

Born, 1889, New Glasgow, N. S. 1904-08, New Glasgow High School. 1907-09, Dalhousie Univ., Halifax. 1909-11, N. S. Technical College. 1909-10, summers, Canadian Geol. Survey.

Present position : 1911 to date, Mining Engineer, Dept. of Ore Mines and Quarries, N. S. Steel & Coal Co., Ltd.

**Edward Chester Congdon**, Duluth, Minn.

Proposed by H. C. Dudley, C. H. Munger, T. F. Cole.

Born, 1885, St. Paul, Minn. 1904, Graduated at The Hill School. 1908, Graduated Yale University with degree of A. B. 1908-13, Employed as an officer of various mining corporations at Duluth, Minn.

Present position : President of Weed Iron Co., Duluth, Minn.

**Angus Ward Davis**, Trail, B. C.

Proposed by Richard S. McCaffery, Francis Jenkins, L. K. Armstrong.

Born, 1877, Montreal, Canada. 1898, B. A. Sc., McGill Univ. 1898-99, British-American Corpn., Rossland. 1899-1900, Republic Mine, Wash. 1904-05, Mining Dept., C. P. R. R.

Present position : 1905 to date, Mining Engineer, Con. Min. & Smelt. Co.

**Ernest Heathcote Dickenson**, New York, N. Y.

Proposed by J. F. Kemp, Charles P. Berkey, Thomas T. Read.

Born, 1886, Nova Scotia, Canada. 1903-07, Laval University, Canada ; Degree A. B. 1908-11, Columbia University, School of Mines. 1907, Canadian Pacific R. R., Construction Work. 1911, Instructor in surveying, Columbia University ; Concentrator of Nevada Cons. Copper Co., McGill, Nev. 1912-13, Engineer, Beatson Copper Co., Latouche, Alaska ; Supt. Midas Copper Co., Valdez, Alaska.

Present position : Treadwell Mines, Douglas Island, Alaska.

**Frederick Charles Dyer**, Toronto, Ont., Canada.

Proposed by Reginald E. Hore.

Born, 1872, Manchester, England. 1886, Public School, Manchester. 1888, Ducie Avenue Org. Science School, Manchester. 1908, Department Mining, Toronto University. Degree of B. A. Sc. 1888-92, Teacher Mathematics and Chemistry, Ducie Ave. Org. Science School, Manchester, England. 1900-01, Master Mechanic, Log Cabin Mining Co. 1901-04, Foreman with E. K. Roche, drilling contractor. 1904-08, Student, etc. 1909-13, Demonstrator, Department Mining Engineering, Toronto University. 1913, Member of firm Banting & Dyer, Engineers, Surveyors and Contractors.

Present position : Lecturer in Mining, Faculty Applied Science and Engineering, University of Toronto.

**William L. Fraser**, Grass Valley, Cal.

Proposed by William Hague, A. D. Foote, Arthur B. Foote.

Born, 1880, Hudson, Mass. Graded and High Schools, Boston, Mass. Have followed mining for about 12 years. Worked for experience in small mines in Boulder Co., Colo. Asst. Supt., Contention mine, Lake City, Colo., since defunct. Prospected Death Valley and operated own property two years ; was in first rush, Tonopah, Goldfield, Manhattan ; leased and owned property. "Scout" work, Nevada, Death Valley and North California for Wilbur E. Sanders.

Present position : last four years, Office and Cost Statistician, North Star Mines.

**John Neil Dinning Gray**, Glasgow, Scotland.

Proposed by G. M. Colvocoresses, Arthur A. Cole, W. G. Miller.

Born, 1884, Glasgow, Scotland. 1890-1900, Albert Academy, Glasgow. 1900-04, Glasgow and West of Scotland Technical College. 1907, Mining, Buffalo Silver Min. Co. ; 1908, Milling and Assaying, Cobalt Central Silver Min. Co., Ltd. ; 1908, Assaying, Tretheway Cobalt Silver Min. Co., Ltd., all of Cobalt, Ont. 1909-10, Partner, Gardner & Gray, Min. Engineers and Assayers, Gowganda, Canada. 1911, Mgr., Dobie-Reeve Silver Min. Co., Gowganda. 1912, Reduction Staff, Nourse Mines, Ltd., Johannesburg, S. A.

Present position : On Reduction Staff, Globe & Phenix G. M. Co., Rhodesia, S. A.

**John Campbell Greenway, Warren, Ariz.**

Proposed by Thomas T. Read, L. D. Ricketts, J. S. Douglas.

Born, 1872, Huntsville, Ala. 1890-91, Univ. of Virginia. 1892-93, Yale Univ., Grad. 1895, Ph. B. 1895-98, Day laborer, Mechanical Dept., Carnegie Steel Co., Duquesne Plant. 1898, Rough Rider in Cuban Campaign. 1902-05, Asst. Supt., Oliver Iron Min. Co., Ishpeming, Mich. 1905-10, Gen. Supt., Canisteo District, Oliver Iron Min. Co., Coleraine, Minn.

Present position : 1910 to date, Gen. Mgr., Calumet & Arizona Min. Co.

**John Percival Hamilton, Milwaukee, Wis.**

Proposed by Richard S. McCaffery, S. W. Traylor, L. K. Armstrong.

Born, 1876, Linden, Mich. 1889-1903, Calumet & Hecla Min. Co. 1903-07, Newport Min. Co., Milwaukee. 1907-10, National Ore Concentration Co. 1910-12, Summit Copper Co.

Present position : 1912 to date, Concentrating Engineer, Power and Mining Machinery Co.

**L. Ogilvie Howard, Globe, Ariz.**

Proposed by Walter Douglas, G. F. G. Sherman, Alexander V. Dye.

Born, 1878, Montreal. Montreal High School. 1895-96, Montreal Collegiate Institute. 1897-1900, McGill Univ. 1900-01, Chemist, Am. Smelt. & Refg. Co., Aguascalientes, Mex. 1902-03, Demonstrator in Metallurgy and Metallurgical Chemistry, McGill Univ. 1904, Chemist, A. S. & R. Co., Aguascalientes. 1905-06, Chemist, Anaconda Copper Co., Anaconda. 1906, Chemist, Arizona Smelting Co., Humboldt, Ariz.

Present position : 1907 to date, Chemist, then Metallurgist, Old Dominion Copper Mining Co.

**Wilbur Judson, Deming, N. M.**

Proposed by Robert Linton, Andrew W. Newberry, C. Colcock Jones.

Born, 1880, Lansing, Mich. 1901, Lawrence Scientific School; S. B. 1902-03, Michigan College of Mines. 1907, Mine Foreman, Capillitas Copper Co., Catamarca, Argentina. 1908, Supt., Inter-Ocean Mine, Sunshine, Colo. 1909, Mine Foreman, Cerro Prieto Mine, Magdalena, Sonora, Mex. 1910-12, Foreman, Sierra Cons. Min. Co., Ocampo, Chihuahua.

Present position : Examining Engineer.

**Raymond Molloy Kateley, Horrabridge, S. Devon, England.**

Proposed by Harold A. Titcomb, A. Chester Beatty, Richard M. Geppert.

Born, 1883, Llantrissant. 1898-1900, Penzance High School. 1900-02, Carn Brea Mine (Practical Mining, etc.). 1902-95, Camborne Mining School (1st Class Certificate). 1906-08, Surveyor and Assayer at South Crofty Mine, Ltd., Cornwall. 1908-10, Assayer and Surveyor, Athabasca Copper Fields, Ltd., Siberia. 1910-11, Surveyor and Manager, Taquah Central Mine, Ltd. 1910-11, Surveyor at Broomassie Mine, Ltd. 1911-13, Asst. Manager and Manager, Filans (Nigeria) Tin Mining Co., Ltd.

Present position : Home on leave.

**L. W. Kemp, Grass Valley, Cal.**

Proposed by William Hague, A. D. Foote, A. B. Foote.

Born, 1886; Berkeley, Cal. 1902-06, Polytechnic High School, San Francisco, Cal. 1907-09, Mackey School of Mines, Reno, Nev. 1906, Mining, Montana-Tonopah Mining Co., Tonopah, Nev. 1907, Mining, Tonopah-Belmont Development Co., Tonopah, Nev. 1909, Assaying, Pittsburg Silver Peak Mining Co., Blair, Nev.

Present position : 1910 to date, Cyanide Foreman, North Star Mining Co.

**Richard A. Leaby, Anaconda, Mont.**

Proposed by E. W. Ellis, C. D. Demond, Pierce Barker.

Born, 1883, Killarney, Ireland. 1909-13, Colorado School of Mines; degree Engineer of Mines. 1904-07, Mechanical draftsman, Llewellyn Iron Works, Los Angeles, Cal. 1907-08, Mechanical draftsman, Southern Arizona Smelting Co., Sasco, Ariz. 1908, Mechanical draftsman, Los Angeles Aqueduct Commission, Cement Plant, Los Angeles, Cal.; Cyanide Mill, Queen Esther Mining & Milling Co., Soledad, Cal. 1911, Mechanical draftsman, Utah Copper Co., Garfield, Utah. 1912, Millman, Tomboy Gold Mines Co., Ltd., Tomboy, Colo.

Present position : Asst. in Testing Department, Washoe Smelter, Anaconda Copper Mining Co.

**Lewis William Ledyard, Ontario, Canada.**

Proposed by Charles E. Schwarz, H. A. Buehler, G. H. Cox.

Born, 1884, Sioux Falls, S. D. 1904-09, S. D. School of Mines; Degree in Met. Engrg. 1905-06, Mill Foreman, Grandview Min. Co., Silver City, S. D. 1909-10, Timberman and driller, Homestake Min. Co., Lead, S. D. 1910-11, Transitman, Hydro-Electric Plant, Homestake Min. Co., Spearfish, S. D. 1911-13, Mine Foreman, Assayer and Surveyor, Twin Butte Min. & Smelt. Co., Twin Butte, Ariz.

Present position : Mine Foreman, North American Smelt. Co., Ltd.

**Charles Legrand, Douglas, Ariz.**

Proposed by Walter Douglas, James Douglas, Cleveland H. Dodge.

Born, 1873, Liège, Belgium. 1879-84, École Primaire, Liège. 1884-87, École Moyenne, Liège. 1887-90, Mechanical and electrical engineering, École Industrielle, Liège. 1891-93, Testing Dept., Canadian Gen. Electric Co. 1893-95, Asst. to Ch. Engr., Royal Electric Co., Montreal. 1896-97, Elec. Engr., C. and C. Electric Co., Garwood, N. J. 1897-1900, Experimental work on electrical instruments. 1900-02, Asst. to Ch. Engr., Mass. Electric Co., Boston. 1902-03, Asst. Cons. Engr., Phelps, Dodge & Co.

Present position : Cons. Engr., Phelps, Dodge & Co.

**Ernest Victor Neelands, Giroux Lake, Cobalt, Ont.**

Proposed by Reginald E. Hore.

Born, 1878, Lindsay, Ontario, Canada. 1886-92, Public School, Lindsay. 1892-96, Collegiate Institute, Lindsay. 1896-1900, University of Toronto, graduated with degree of Bachelor of Applied Science. 1902-03, Fellowship, University of Toronto. 1897-98, Surveying, North Ontario, with A. Niven. 1899, General Mining, Le Roi Mine, for W. A. Carlyle. 1900, Geologist for Ont. Govt. Exploration. 1901-02, Assayer St. Eugene Mine, for James Cronin. 1902, Staff, Le Roi No. 2 Mine, Roseland. 1903, Supt. Monument Bay Mine, Kenora, for J. McCuaig, Toronto. 1903, Reporting for Gooderham & Blackstock, Toronto. 1904, Shift-Boss, Stratton's Independence. 1905, Supt. Massey Station Mine, for H. W. Hardinge. 1906-07, Manager Black Queen Mine, for H. W. Hardinge.

Present position : Manager Cobalt Comet Mines, Ltd., and Manager Hargrave Silver Mines, Ltd., Cobalt, Ont.

**Irwin Balmer Neilly, Cobalt, Ont., Canada.**

Proposed by Reginald E. Hore.

Born, 1883, Bradford, Ont. 1890-97, Public School, Aurora, Ont. 1897-1901, High School, Bradford Ont. 1903-08, Faculty of Applied Science, University of Toronto. 1907, Graduated in Mining Engineering. 1908, Degree of B. A. Sc. 1908, Greater Canada Mining Co., Ltd., operating at Crystal, Colo. 1908-09, Assayer and surveyor with Silver Queen Mining Co., Ltd., Cobalt, Ont.; Robert A. Brice, Cobalt, Ont., at that time Supt. 1909-13, Manager for Black Mines, Consolidated, Ltd.; John Black, Pres., 233 Board of Trade Bldg., Montreal, P. Q. 1909-12, Manager Wyandoh Silver Mines, Ltd., Cobalt, Ont.; Ales. Pringle, Pres., Coristine Bldg., Montreal, P. Q.

Present position : 1912 to date, Supt. Mine and Mill for Penn-Canadian Mines, Ltd.; W. J. Haines, Pres., 1011 Chestnut St., Philadelphia, Pa.

**Charles Oscar Olsen, Wardner, Idaho.**

Proposed by Nelson S. Greensfelder, L. K. Armstrong, Richard S. McCaffery.

Born, July 9, 1887, Murray, Ida. 1911, Colorado School of Mines; E. M., 1911-13, Hand Mining in Danville, Wash., Mucker, Trammer, Machine Helper and Machine-man, B. H. & S. M. & C. Co. Machine-man, Timber Helper and Timberman, Federal M. & S. Co.

Present position : Surveyor's Helper, Federal M. & S. Co.

**Sidney Paige, Washington, D. C.**

Proposed by Arthur C. Spencer, C. E. Siebenthal, E. W. Parker.

Born, 1880, Washington, D. C. 1901-03, University of Michigan. 1907-08, Graduate School, Yale, Scholarship. 1899-01, two years with Nicaragua Canal Commission. 1907, Asst. Geologist to Panama Canal Commission.

Present position : 1902 to date, with U. S. Geological Survey as Geologist.

**William Quirinus Ranft, Superior, Mont.**

Proposed by Horace V. Winchell, F. F. Sharpless, Otto Sussman.

Born, 1869, Baltimore, Md. 1909 to date, President, Iron Mountain Tunnel Co. 1907 to date, President, Robert Emmet Copper Co., of Montana. 1911 to date, Gen. Mgr., Blue Bird Corbin Gold, Silver & Copper Co.

**Walter Leigh Remick, Juneau, Alaska.**

Proposed by Erle V. Daveler, B. L. Thane, J. R. Whipple.

Born, 1883, Methuen, Mass. 1900-04, Thayer Academy, So. Braintree, Mass. 1905-09, Harvard Univ.; A. B. 1913, Alexander Hamilton Institute, Astor Place, New York. 1909-10, Tacoma Smelting Co. 1910-11, Chemist, Western Steel Corp'n. 1912, Supt. of Mill, Goldstream Min. Co., Ketchikan, Alaska. 1912-13, Chemist, Superior Cement Co., Concrete, Wash.

Present position : Sampling Dept., Alaska Gastineau Min. Co.

**Cyrus Robinson, Mt. Vernon, N. Y.**

Presented by Karl Eilers, Willard S. Morse, Robert S. Towne.

Born, 1869, England. Mechanical Engineer, Technical College, Bradford, England. Owens College, Manchester, England. Formerly a member. (Elected 1895, Resigned 1904.)

Present position: Consulting Engineer.

**August Sandberg, Bisbee, Ariz.**

Proposed by Walter Douglas, G. F. G. Sherman, Alexander V. Dye.

Born, 1868, Sweden. 1890-97, Univ. of Lund, Sweden; Ph. D. 1897-98, Chemist, Phelps, Dodge & Co., New York. 1898-1900, Chemist, Detroit Copper Min. Co. of Arizona. 1900-03, Metallurgist, Moctezuma Copper Co., Sonora, Mex. 1903-06, Metallurgist, Transvaal Copper Min. Co., Sonora, Mex. 1906-11, Chemist and Metallurgist, Cananea Cons. Co., Moctezuma Copper Co., and Transvaal Copper Min. Co. 1911-12, Explorations in northern Canada.

Present position: 1912 to date, on engineering staff, Phelps, Dodge & Co.

**Henry W. Saunders, Gary, W. Va.**

Proposed by Howard N. Eavenson, E. O'Toole, N. H. Mannakee.

Born, 1879, Petrolia, Ont., Canada. 1891-97, High School. 1897-1900, Graduated in Mining Engineering, School of Practical Science, Toronto University. 1900-01, Post-graduate Course, obtaining degree Bachelor of Applied Science, University of Toronto. 1901-02, Geologist, Lake Superior Power Co., Sault Ste. Marie, Ont. 1902-3, Mining Engineer, C. P. Collins, Johnstown, Pa.; Draftsman, Lorraine Steel Co.; Draftsman, Cambria Steel Co., Johnstown, Pa. 1903-1905, Draftsman on Construction and Mining work. 1906-10, Chief draftsman, United States Coal & Coke Co., Gary, W. Va.

Present position: 1910 to date, Division Engineer of the above company in charge of all underground engineering work and part of construction work, in their mines, 12 plants.

**Lewis Searing, Denver, Colo.**

Proposed by Richard A. Parker, Frank Bulkley, John W. Finch.

Born, 1866, New York, N. Y. 1888, Stevens Institute of Technology; M. E. 1895, Vice-President and General Manager, Denver Engineering Works Co. Designed and installed power and pumping plants for coal and metal mines.

**Horace H. Smith, Juneau, Alaska.**

Proposed by Erle V. Daveler, B. L. Thane, J. R. Whipple.

Born, 1880, Bodie, Cal. 1899, Graduated Oakland High School, Cal. 1902, Assaying, R. A. Perez. 1903, Assaying, Gold Bronze Mining Co.; Milling, Daly-Judge Mining Co. 1904-05, Copper Milling, Honerive Mining & Milling Co., Utah. 1906, Shift Boss, Honerive Mining Co. 1907-10, Night Foreman, U. S. Smelting Co., Lead Concentrator. 1910-12, Mill Supt., Austin Manhattan Cons. Mining Co.

Present position: Asst. Supt. of Mills, Alaska Gastineau Mining Co.

**Maximilian George Ferdinand Sohnlein, Machacamarca, Bolivia, S. A.**

Proposed by H. F. Grondijs, Henry S. Munroe, Charles C. Swartz.

Born, 1885, Amsterdam, Holland. 1891-97, Grammar School, Haarlem, Holland. 1897-1902, High School, Haarlem, Holland, Graduated. 1902-03, Practice in machine-shops, Figee Bros., Haarlem. 1903-8, Delft Univ.; E. M. 1908-09, Asst. of mine surveying, Delft Univ. 1909-11, Engineer, Sepingan Gold Min. Co., Samsas, Borneo. 1911, Engineer and assayer, Tecolote Copper Co., Carbó, Sonora, Mex. 1912, Supt., Socavón, de la Virgen Mine, Cia. Minera de Oruro, Bolivia.

Present position: Supt. Concentrating Plant, Cia. Minera de Oruro.

**Frederick W. Solomon, Miami, Ariz.**

Proposed by J. Parke Canning, B. Britton Gottsberger, R. C. Canby.

Born, 1870, Cornwall, England. 1883, English Common Schools. 1909-10, Special course in concentrating, etc., Int. Correspondence Schools. 1885-89, Boiler maker's apprentice, England. 1890-92, Mill man, South Galena Min. & Mill. Co., Bingham Canyon, Utah. 1892-1902, various positions, Mercur Min. & Mill. Co.; Highland Boy Gold Min. Co.; West Mountain Placer Min. Co.; Queen Mill; California Min. & Mill. Co. 1902-06, Night concentrator foreman, Ohio Copper Co., Bingham Canyon, Utah. 1906-08, Gen. concentrator foreman, Utah Copper Co. 1908-11, Gen. con. foreman and Asst. Con. Supt., Nevada Cons. Copper Co., Miami, Ariz.

Present position: Concentrator Supt., Miami Copper Co.

**James Beverley Stapler, Grass Valley, Cal.**

Proposed by William Hague, Arthur B. Foote, Robert H. Bedford.

Born, 1890, Wilmington, Del. 1904-08, Taft's School, Watertown, Conn. 1908-11, Cambridge University, England; B. A. degree. 1910, Brayton Domain Collieries, Cumberland, England; Mgr., George H. Askew. 1911 to date, North Star Mines Co., Grass Valley, Cal.; Mgr., Arthur B. Foote.

Present position: Timekeeper, North Star Mines Co.

**John Stewart, Bluefield, W. Va.**

Proposed by John J. Lincoln, Howard N. Eavenson, William D. Ord.

Born, 1864, Morantown, Md. 1870-82, Public Schools of Lonaconing, Md. 1882-88, Public Schools and home night studies; prepared for Lehigh Univ. 1888-89, Lehigh Univ. 1889-94, Clerk to Commissioners, Allegheny Co., Md. 1894-97, Lehigh Univ.; B. S. 1876-88, Practical coal mining, New Central Coal Co. and Georges Creek Coal & Iron Co., Lonaconing, Md. 1897-1900, Division Engr., Berwind White Coal Min. Co. 1900-01, Division Engr., Frick Coke Co. 1901-04, Engr. & Supt., New Central Coal Co. 1904-05, Mine Engr., U. S. Coal & Coke Co. 1905-06, Inspector, Ellsworth Coal Co. 1906-08, Gen. Supt. & Engr., Century Coke Co. 1908-11, Engr. & Supt., Va.-Pocahontas Coal Co. 1911-12, Gen. Supt., Canadian Collieries Co.

Present position: Member Car Allotment Commission, Norfolk & Western R. R.

**Jesse C. Stoddard, Wharton, N. J.**

Proposed by Henry S. Drinker, Benjamin L. Miller, Howard Eckfeldt.

Born, 1886, Washington, D. C. 1901-05, McKinley Manual Training School, Washington, D. C. 1905-1909, Lehigh Univ.; E. M. 1909-11, Engr., Juragua Iron Co., Santiago de Cuba. 1911-12, Bethlehem Steel Co. Examination work in Honduras, Mexico, and Chile.

Present position: Engr., Empire Steel & Iron Co., Mt. Hope Division.

**Daniel P. Sullivan, Butte, Mont.**

Proposed by B. H. Dunshee, E. H. Wilson, A. C. Carson.

Born, 1877, Michigan. Graduate of High School, Marysville, Mont. No technical education. 1896-98, Mining, Drumlummon, Marysville. 1899, Mining, Anaconda Mine, for John O'Neal. 1900, Timbering, Nipper Mine. 1901, Timbering, Gagnon Mine. 1902-10, Shift Boss for Charles J. Adams and J. E. Sullivan. 1912-13, Foreman, Gagnon Mine.

Present position: Supt., Gagnon and Original Mines.

**Grant Heatly Tod, Oakland, Cal.**

Proposed by H. Foster Bain, Thomas T. Read.

Born, 1872, Simla, India. 1882-87, Brighton College, England. 1888-90, Blairlodge School, Scotland. 1891-93, School of Mines, Clausthal, Germany. 1895-1900, Various mines in South Africa. 1900-11, Homestake Mining Co., Lead, S. D., under direct supervision of Mr. B. C. Yates, Asst. Chief Engineer. 1911, Coast Mfg. & Supply Co., of Oakland, Cal.; Mr. A. H. Merritt, Gen. Mgr.

Present position: Technical Representative for Coast Manufacturing & Supply Company, Oakland, Cal. (Mfrs. of Safety Fuse.)

**Merwin H. Ward, Everett, Mass.**

Proposed by C. L. Colburn, John B. N. Dorr.

Born, 1888, Lewiston, Me. 1903, Mass. Institute of Technology. 1913, Colorado School of Mines; E. M.

Present position: Metallurgical Dept., Butte Duluth Mining Co., Butte, Mont.

**Clarence LeRoy Wickstrom, Spokane, Wash.**

Proposed by Richard S. McCaffery, Francis Jenkins, L. K. Armstrong.

Born, 1880, Clay Center, Kansas. 1907, Univ. of Idaho; B. S. 1906-08, Federal M. & S. Co., Wardner, Ida. 1908, Asst. Engr., surveys, reports, etc., Cœur d'Alène District, Ida. 1909, Chief Engr., Spokane Canal Co., Spokane, Wash.

Present position: Consulting Engineer.

**Daniel J. Williams, Butte, Mont.**

Proposed by Oscar Rohn, G. G. Vivian, J. H. Warner.

Born, 1884, Mountain Ash, Wales, G. B. 1903-04, Washington State College. 1905-08, Montana State School of Mines. 1908-1910, Mining Engineer, Pittsburg & Montana Copper Co. 1910-11, Mining Engineer, East Butte Copper Mining Co. 1911-13, Mine Supt., East Butte Copper Mining Co. 1913, Asst. Genl. Mgr., same company.

Present position: Genl. Mgr., Continental Development Co.

**John Sidney Williams, Nacozari, Sonora, Mexico.**

Proposed by Walter Douglas, Gerald Sherman, Alexander V. Dye.

Born, 1872, England. General, no technical, education. 1888-90, Banking and commercial experience. 1890-1900, General office, Copper Queen Cons. Min. Co. 1900-13, Asst. Supt., Supt., Gen. Mgr., The Moctezuma Copper Co.

Present position: General Manager, The Moctezuma Copper Co.

*Associate.*

**Warren Jenney, Anaconda, Mont.**

Proposed by E. P. Mathewson, C. D. Demond, Louis V. Bender.

Born, 1871, Boston, Mass. 1879-90, Public Schools, Brookline, Mass. 1890-92, Mass. Institute of Technology. 1893-1900, Clerical Work with Boylston Fire Insurance Co., Brookline Gas Light Co. and Dorchester Gas Co. 1900-13, Clerical work with Anaconda Copper Mining Co. Years 1902-13 devoted exclusively to metallurgical and cost accounting.

Present position: Metallurgical Accountant, Anaconda Copper Mining Co.

*Junior Members.*

**Kai Chi Chow, New York, N. Y.**

Proposed by Thomas T. Reed, Robert Peele, Arthur L. Walker.

Born, 1889, Shanghai, China. 1910, Entered Columbia University School of Mines and still a student. 1911, Kingston Coal Co., Pa., two weeks. Summer, 1912, Tennessee Copper Co., Ducktown, Tenn., six weeks.

Present position: Student at School of Mines, Columbia University.

**Eugene George Snedaker, Golden, Colo.**

Proposed by Harry J. Wolf, William R. Chedsey, F. W. Traphagen.

Born, July 26, 1890, Aspen, Colo. Employed in Cyanide Mill of Cornucopia Mines Co. of N. Y., Cornucopia, Ore., for summer of 1913. Worked in all departments of mill. Retained as Engineer of Eureka Coal Mine near Bongmont, Colo., owned by Dr. W. M. Spitzer, Metropolitan Bldg., Denver.

Present position: Senior Student at Colorado School of Mines.

**Henry Tackmann, New York, N. Y.**

Proposed by Henry S. Munroe, E. L. Kurtz, Robert Peele.

Born, 1892, New York City. 1899-1906, New York Public Schools. 1906-09, Townsend Harris Hall, C. C. N. Y. 1909-13, School of Mines, Columbia University. 1912, Studied two months at the mines on Menominee Range and in the copper country, Mich., underground and on surface.

Present position: Completing fourth year work at Columbia and will receive degree of E. M. in October.

*Change of Status.*

**Willis Eugene Barnum, Pachuca, Hidalgo, Mexico.**

Born, 1880, Holley, N. Y. 1899, Graduate Albion High School, Albion, Orleans Co., N. Y. One and one-half years Cornell University, Ithaca, N. Y. Special course 1900-01, 1901-02, Did not receive a degree, being obliged to leave college on account of money. 1906-08, Shift man, Black Mountain Mining Co., Sonora, Mexico; N. C. Banks, Mgr. 1908-10, Shift man, Blaisdell Coscotitlan Syndicate, Pachuca, Mexico; H. A. Barker, Mgr. 1910-11, Asst. Supt. same company.

Present position: 1911 to date, Supt. same company; J. P. Warr, Mgr.

**S. Ken Huang, Tayeh Iron Mines, Tayeh, China.**

## CHANGES OF ADDRESS OF MEMBERS.

The following changes of address of members have been received at the Secretary's office during the month of September, 1913. This list, together with the lists published in *Bulletin* Nos. 76 to 81, April to September, 1913, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Mar. 1, 1913, and brings it up to the date of Oct. 1, 1913.

|                           |                                                                |
|---------------------------|----------------------------------------------------------------|
| AMSDEN, O. B.             | P. O. Box 431, Victor, Colo.                                   |
| BACKUS, GEORGE S.         | Instructed to hold all mail.                                   |
| BAIRD, DUDLEY             | Pacific Foundry Co., Harrison & 18th Sts., San Francisco, Cal. |
| BARBER, R. J., Min. Engr. | 88 Broad St., Boston, Mass.                                    |
| BARNARD, E. A.            | 612 W. 5th St., Anaconda, Mont.                                |
| BLAIR, ALLEN F.           | 318 First Ave., So., Seattle, Wash.                            |
| BLOOD, GEORGE D.          | 716 Newhouse Bldg., Salt Lake City, Utah.                      |
| BOUTWELL, JOHN M.         | Old Dominion Copper Mining & Smelting Co., Globe, Ariz.        |
| BOYLE, EMMET D.           | Carson City, Nev.                                              |



|                                                                                                         |                                                                  |
|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|
| BROWN, HALCOMBE J., Keystone Fireproofing Co., Marbridge Bldg.,<br>34th St. & Broadway, New York, N. Y. |                                                                  |
| BROWN, J. J., JR.                                                                                       | Troy, Ill.                                                       |
| BURT, CHARLES S.                                                                                        | 724 E. University St., Ann Arbor, Mich.                          |
| CAHEN, JAMES P., JR.                                                                                    | 419 Chestnut St., South Bethlehem, Pa.                           |
| CARLYLE, WILLIAM A., Cons. Min. Engr.                                                                   | 62 London Wall, London, E. C., England.                          |
| CHESEY, WILLIAM R.                                                                                      | Asst. Prof. of Mining, Colo. School of Mines, Golden, Colo.      |
| COHEN, M. B.                                                                                            | 100 W. 143d Street, New York, N. Y.                              |
| CRANSTON, ROBERT E.                                                                                     | 437 Holbrook Bldg., San Francisco, Cal.                          |
| DALBERG, FRANK A.                                                                                       | Arctic Coal Co., Tromsø, Norway.                                 |
| DEAN, A. L.                                                                                             | Care Quebec Bank, Quebec, Canada.                                |
| DENNY, HARRY S.                                                                                         | Salisbury House, London, E. C., England.                         |
| DESHLER, GEORGE O.                                                                                      | Utah Metals Co., Bingham Canyon, Utah.                           |
| DEWEY, C. E.                                                                                            | 211 Boston Bldg., Denver, Colo.                                  |
| DOUGLAS, JAMES S.                                                                                       | P. O. Box 888, Douglas, Ariz.                                    |
| DRAPER, FRED W.                                                                                         | Nevyansk, Dept. of Perm, Russia.                                 |
| DUNKIN, DAMON D., Supt., McAlester Coal & Coke Co.                                                      | Buck, via Carbon, Okla.                                          |
| DUNSTAN, ALFRED J.                                                                                      | Roseville Ave., Roseville, N. S. W., Australia.                  |
| DURANT, HENRY T., Care Inst. of Min. and Met.                                                           | Salisbury House, London, E. C., England.                         |
| EDWARDS, J. WARNER.                                                                                     | 1347 Court Place, Denver, Colo.                                  |
| FLAGG, ARTHUR L.                                                                                        | Kelvin-Sultana-Copper Co., Kelvin, Ariz.                         |
| FRASER, LEE.                                                                                            | Apartado 168, Oruro, Bolivia, So. America.                       |
| FULLER, JOHN T.                                                                                         | P. O. Box 393, Little Rock, Ark.                                 |
| FYFE, ALEXANDER.                                                                                        | 74 Cedar St., Roxbury, Boston, Mass.                             |
| GABLICH, HERMAN.                                                                                        | St. Louis Smelting & Refining Co., Liggett Bldg., St. Louis, Mo. |
| HAMMAN, JOHN S.                                                                                         | 19 Harmony Pl., Salt Lake City, Utah.                            |
| HARDY, J. GORDON.                                                                                       | Room 1812, 165 Broadway, New York, N. Y.                         |
| HAWKHURST, ROBERT, JR.                                                                                  | Care International Bank, 60 Wall St., New York, N. Y.            |
| HOFMEYER, CHARLES A.                                                                                    | 16 Rue de Berlin, Paris, France.                                 |
| HUMPHREY, CHARLES.                                                                                      | Hotel Goldfields, Timmins, Ont., Canada.                         |
| INGLIS, J. F.                                                                                           | 1004 W. Quartz St., Butte, Mont.                                 |
| INOUE, TADASHIRO.                                                                                       | 560 Naka-Shibuya, Toyotama-Gori, Tokyo, Japan.                   |
| JOHNSTON, RODERICK L.                                                                                   | 1271 Broadway, New York, N. Y.                                   |
| KING, ERNEST W., Prest. Nevada New Mines Co.                                                            | Rawhide, Nev.                                                    |
| KIRCHEN, CHARLES.                                                                                       | 407 Madison Ave., Grand Rapids, Mich.                            |
| LAIRD, GEORGE A.                                                                                        | Great Cobar Mines, Ltd., Cobar, N. S. W., Australia.             |
| LANDERS, WILLIAM H.                                                                                     | New Almaden, Cal.                                                |
| LAVERY, VAUGHAN M.                                                                                      | 1301 Greenwood Ave., Wilmette, Ill.                              |
| LEWALD, E. A.                                                                                           | Blessing, Texas.                                                 |
| LITTLE, JAMES B.                                                                                        | Headingly, Kenilworth, Cape Colony, So. Africa.                  |
| LONDON, C. J.                                                                                           | 901 Bailey Bldg., Philadelphia, Pa.                              |
| LUCAS, A. F.                                                                                            | 2300 Wyoming Ave., Washington, D. C.                             |
| MCCLEURE, DAVID.                                                                                        | Soquel, Santa Cruz Co., Cal.                                     |
| MCDONALD, BERNARD.                                                                                      | 1005 Fair Oaks Ave., South Pasadena, Cal.                        |
| MACDONALD, BERNARD.                                                                                     | 1005 Fair Oaks Ave., South Pasadena, Cal.                        |
| MACNUTT, C. H., Mgr., Burma Mines, Ltd.                                                                 | Namtu, Northern Shau States, Burma.                              |
| MADGE, WILLIAM C., Care W. G. Perkins & Co.                                                             | 62 London Wall, London, E. C., England.                          |
| MALITZ, EDMUND VON.                                                                                     | Jones & Laughlin, Aliquippa Works, Woodlawn, Pa.                 |
| MATTER, WILLIAM F., Acting Genl. Mgr., Lackawanna Iron & Coal Co.,<br>516 Spruce St., Scranton, Pa.     |                                                                  |
| MERRILL, MONROE E.                                                                                      | 1923 Morgan Place, Hollywood, Cal.                               |
| MOFFAT, DAVID D., Supt. of Mills, Ray Cons. Copper Co.                                                  | Hayden, Ariz.                                                    |
| NOLD, FREDERICK B.                                                                                      | Lansford, Carbon Co., Pa.                                        |
| NORTH, W. O.                                                                                            | 3742 8th St., San Diego, Cal.                                    |
| PALMER, IRVING A.                                                                                       | 623 High Street, Easton, Pa.                                     |
| PETERS, RICHARD, JR., Mfr. Coke, W. J. Rainey Estate, 1st National Bank Bldg.,<br>Uniontown, Pa.        |                                                                  |
| PORTER, JOHN J.                                                                                         | Security Cement & Lime Co., Hagerstown, Md.                      |
| POTTER, EDWARD C.                                                                                       | 1419 Seventh Ave. W., Seattle, Wash.                             |
| PRINGLE, CHARLES A.                                                                                     | Care Pringle Co., Russ Bldg., San Francisco, Cal.                |
| PRITCHETT, C. W.                                                                                        | 2735 Boulevard F, Denver, Colo.                                  |
| RADER, CHARLES I.                                                                                       | Point Loma P. O., San Diego Co., Cal.                            |
| SANDERS, B. H., Benue Syndicate, Ltd., Waiyo, Wamba, Iemaa, Nathem, Nigeria,<br>West Africa.            |                                                                  |

|                                                                                  |                                                   |
|----------------------------------------------------------------------------------|---------------------------------------------------|
| SMYSER, ALBERT E.....                                                            | P. O. Box 303, New Philadelphia, Ohio.            |
| SMYTHE, H. V., Northern Pyrites Co., Northpines, G. T. P. Ry., Via Fort William, | Ont., Canada.                                     |
| SWEETSER, RALPH H., Prest. and Genl. Mgr., Thomas Iron Co.....                   | Easton, Pa.                                       |
| THOMSON, ROBERT W., Care R. R. Hedley, 405 Carter Cotten Bldg.,                  | Vancouver, B. C., Canada.                         |
| TOWER, GEORGE W., JR.....                                                        | 134 Woodland Ave., New Rochelle, N. Y.            |
| UPTON, GEORGE B., Vice-Prest. and Genl. Mgr., Oro Grande Mines Co.,              | Wickenburg, Ariz.                                 |
| VEATCH, J. ALLEN.....                                                            | 497 Pine St., Napa, Cal.                          |
| VILLALON, JOSE R., Secy. Public Works, Public Works Dept.....                    | Havana, Cuba.                                     |
| WANG, CHUNG YU, Kau Tan Tze Bldg., 37 Ching Yuen St., Western District,          | Canton, China.                                    |
| WEED, WALTER HARVEY.....                                                         | Houghton, Mich., and 42 Broadway, New York, N. Y. |
| WHITTIER, CHARLES C.....                                                         | 905 McGill Bldg., Montreal, Canada.               |
| WILDING, JAMES, JR.....                                                          | 101 Edith Street, Oakland, Cal.                   |
| WILFLEY, C. R., Min. Engr.....                                                   | P. O. Box 1721, Denver, Colo.                     |
| WILKINSON, DAVID., S. Newmann & Co., P. O. Box 485,                              | Johannesburg, Transvaal, So. Africa.              |
| WILLIAMS, E. H.....                                                              | 1799 E. 63d St., Cleveland, Ohio.                 |
| WISHON, WALTER W.....                                                            | 616 S. Olive St., Los Angeles, Cal.               |
| WOOD, CARL L.....                                                                | Lyons, Ohio.                                      |

## ADDRESSES OF MEMBERS AND ASSOCIATES WANTED.

| Name.                              | Last Address of Record, from which Mail has been Returned. |
|------------------------------------|------------------------------------------------------------|
| Armstrong, Richard E., . . . . .   | 416 E. So. 2d St., Salt Lake City, Utah.                   |
| Bentley, Thomas H., . . . . .      | 603 Blake-McFall Bldg., Portland, Ore.                     |
| Casey, John P., . . . . .          | 1509 Montana St., El Paso, Tex.                            |
| Crary, Charles N., . . . . .       | Valdez, Alaska.                                            |
| David, W. M., . . . . .            | Care C. G. Hussey & Co., Second Ave., Pittsburg, Pa.       |
| Ederheimer, Leopold, . . . . .     | Maine Mining & Mfg. Co., 52 Broadway, New York, N. Y.      |
| Ferguson, Donald, . . . . .        | P. O. Box 644, Goldfield, Nev.                             |
| Fergusson, Hugh B., . . . . .      | 216 Loo Bldg., Vancouver, B. C., Canada.                   |
| Finletter, John R., . . . . .      | 625 St. Francis Hotel, San Francisco, Cal.                 |
| Geisendorfer, Henry A., . . . . .  | Ariz-Nev. Copper Co., Hillside, Ariz.                      |
| Grove, Independence, . . . . .     | Amparo Mining Co., Etzatlan, Jal., Mexico.                 |
| Heywood, William A., . . . . .     | 4 Broad St. Pl., London, E. C., England.                   |
| Hollis, B. W., . . . . .           | Silverton, Colo.                                           |
| Horschitz, Richard J., . . . . .   | P. O. Box 453, Haileybury, Ont., Canada.                   |
| Johnson, Alexander T., . . . . .   | Yellow Pine Mining Co., Good Springs, Nev.                 |
| Johnson, Dion L., . . . . .        | 325 Water St., Pittsburg, Pa.                              |
| Keller, Cornelius H., . . . . .    | Apartado 134, Parral, Chih., Mexico.                       |
| Kiddie, Thomas, . . . . .          | 884 Bute St., Vancouver, B. C., Canada.                    |
| Lampshire, John O., . . . . .      | Vulture Mine, Wickenburg, Ariz.                            |
| Lehmer, Frank W., . . . . .        | Cia Minera Zapoteca, Ocotlan, Oax., Mexico.                |
| MacKay, Phillip A., . . . . .      | "Illinois," Winmura Pl., Melbourne, Vic., Australia.       |
| Malins, Francis A., . . . . .      | Metates Mine, San Marcos, Sin., Mexico.                    |
| Moore, Roy W., . . . . .           | P. O. Box 48, Velasco, Tex.                                |
| Nelson, D. W. C., . . . . .        | Baker City, Ore.                                           |
| Peterson, Frank, . . . . .         | H. W. Hellman Bldg., Los Angeles, Cal.                     |
| Potter, Charles F., . . . . .      | 215 First National Bank Bldg., San Francisco, Cal.         |
| Rathborne, Merwyn R. W., . . . . . | Amargosa, via Las Vegas, Nev.                              |
| Reynolds, Llewellyn, . . . . .     | Socorro Mines, Mogollon, N. M.                             |
| Russell, Branch E., . . . . .      | Apartado 22, Nacozari, Son., Mexico.                       |
| Schroder, Harold, . . . . .        | English and Aust. Copper Co., Wasatah, Tasmania.           |
| Stoddart, A. W., . . . . .         | 638 Salisbury House, London, E. C., England.               |
| Sturges, Harold, . . . . .         | Oaxaca, Oax., Mexico.                                      |
| Van Ness, William W., . . . . .    | 622 Salisbury House, London, E. C., England.               |
| Vincombe, Robert E. B., . . . . .  | Post Restante, Vladikaffkas, So. Russia.                   |

|                                |                                                                             |
|--------------------------------|-----------------------------------------------------------------------------|
| Watson, Ralph W., . . . . .    | Calloo, Utah, Clifton Mail box.                                             |
| Webster, Erastus H., . . . . . | Hotel Cosmopolita, Guadalajara, Jal., Mexico.                               |
| Wheeler, Aubrey S., . . . . .  | Box 48, Salisbury, Rhodesia, So. Africa.                                    |
| Williams, John R., . . . . .   | Care Standard Bank of So. Africa, 10 Clements Lane, London, E. C., England. |
| Woods, Clarence, . . . . .     | Shawmut, Cal.                                                               |

## NECROLOGY.

The deaths of the following members were reported to the Secretary's office during the month of September, 1913:

| Date of Election. | Name.                             | Date of Decease.    |
|-------------------|-----------------------------------|---------------------|
| 1895              | **Britten, Thomas J., . . . . .   |                     |
| 1899              | *Cox, Jennings S., Jr., . . . . . | August 31, 1913.    |
| 1876              | *Daniels, Fred H. . . . .         | August 31, 1913.    |
| 1872              | †Ingham, William A. . . . .       | September 23, 1913. |
| 1890              | *Mannesmann, Robert, . . . . .    | July 8, 1913.       |
|                   | * Member.                         | ** Life Member.     |
|                   |                                   | † Associate.        |

## STANDING COMMITTEES.

*Executive.*CHARLES F. RAND, *Chairman.*JAMES F. KEMP,  
ALBERT R. LEDOUX,JOSEPH W. RICHARDS,  
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DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Dec. 1, 1913. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## The Influence of Various Elements on the Absorption of Carbon by Steel.\*

BY ROBERT E. ABBOTT, CLEVELAND, OHIO.

(New York Meeting, October, 1913.)

THE influence of various elements in retarding or accelerating the absorption of carbon during the process of carburization is fairly well known. In general those elements which form carbides accelerate the absorption, while those which do not retard it. It has sometimes been wrongly stated that those elements which raise the temperature of the critical range increase the absorption, while those which lower this temperature decrease it. Silicon is a notable exception to this rule, for its influence is to raise the critical range but to lower the absorption of carbon. Some elements which do not form carbides have no apparent influence upon the absorption rate. Carbon itself retards the absorption rate.

With a view to obtaining more exact data upon the subject the following experiments were undertaken: 208 steels of different chemical composition were selected to represent most of the types of modern constructional steels. Specimens  $\frac{3}{4}$  in. in diameter and  $\frac{3}{4}$  in. in length were weighed to milligrams. They were then packed in the special carburizing box shown in Fig. 1, and kept in the furnace for 10 hours at a temperature of 900° C. A duplicate experiment was conducted at 1,000° C. At equal intervals of time the box was rotated in the furnace so that two complete revolutions were made in the 10 hours. This precaution was taken to neutralize as much as possible any effect of unequal heating. At the end of the 10 hours the box was allowed to cool in the furnace with the doors open. The specimens were then weighed again and the increased weight (carbon) determined. In the following table are given the analyses of the various steels, together with the increased weight of carbon expressed in milligrams.

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\* Contributed by the Metallurgical Laboratory of the Peerless Motor Car Co.

| Mark.                        | Chemical Analysis. |      |       |       |       |       |      |       | Increased Weight in Mg. |           |
|------------------------------|--------------------|------|-------|-------|-------|-------|------|-------|-------------------------|-----------|
|                              | C.                 | Ni.  | Cr.   | V.    | P.    | S.    | Mn.  | Si.   | 900° C.                 | 1,000° C. |
| Group 1, 8 per cent. Nickel. |                    |      |       |       |       |       |      |       |                         |           |
| U4                           | 0.298              | 8.00 | 0.45  | 0.07  | 0.011 | 0.021 | 0.42 | 0.112 | 92                      | 169       |
| Group 2, 6 per cent. Nickel. |                    |      |       |       |       |       |      |       |                         |           |
| MMM                          | 0.292              | 6.00 | 0.26  | ..... | 0.033 | 0.023 | 0.54 | 0.131 | 94                      | 172       |
| Group 3, 5 per cent. Nickel. |                    |      |       |       |       |       |      |       |                         |           |
| BU                           | 0.365              | 5.00 | ..... | ..... | 0.027 | 0.027 | 0.53 | 0.141 | 103                     | 151       |
| OO                           | 0.151              | 5.20 | 0.08  | ..... | 0.014 | 0.012 | 0.58 | 0.137 | 54                      | 187       |
| PPP                          | 0.072              | 5.14 | 0.27  | 0.02  | 0.017 | 0.011 | 0.29 | 0.127 | 95                      | 206       |
| Group 4, 4 per cent. Nickel. |                    |      |       |       |       |       |      |       |                         |           |
| KE                           | 0.390              | 4.14 | ..... | ..... | 0.013 | 0.030 | 2.5  | 0.254 | 64                      | 154       |
| SI                           | 0.185              | 4.35 | 0.20  | ..... | 0.013 | 0.048 | 0.41 | 0.009 | 104                     | 217       |
| Group 5, Chrome-Nickel.      |                    |      |       |       |       |       |      |       |                         |           |
| BE                           | 0.500              | 5.12 | 1.03  | ..... | 0.009 | 0.035 | 0.27 | 0.192 | 29                      | 135       |
| TE                           | 0.275              | 4.97 | 1.35  | 0.06  | 0.010 | 0.020 | 0.37 | 0.192 | 101                     | 208       |
| AE                           | 0.208              | 5.21 | 1.22  | 0.04  | 0.009 | 0.017 | 0.41 | 0.173 | 68                      | 213       |
| SSS                          | 0.168              | 4.61 | 1.65  | 0.03  | 0.018 | 0.010 | 0.36 | 0.291 | 86                      | 213       |
| Group 6, Chrome-Nickel.      |                    |      |       |       |       |       |      |       |                         |           |
| N2                           | 0.364              | 4.40 | 1.37  | 0.07  | 0.009 | 0.022 | 0.42 | 0.240 | 85                      | 190       |
| N6                           | 0.311              | 4.30 | 1.28  | ..... | 0.014 | 0.021 | 0.30 | 0.196 | 87                      | 194       |
| N1                           | 0.130              | 4.05 | 1.00  | 0.07  | 0.013 | 0.019 | 0.32 | 0.158 | 80                      | 200       |
| D5                           | 0.120              | 4.32 | 1.31  | 0.08  | 0.009 | 0.027 | 0.47 | 0.159 | 141                     | 206       |
| Group 7, Nickel.             |                    |      |       |       |       |       |      |       |                         |           |
| GGG                          | 0.332              | 3.75 | ..... | ..... | 0.015 | 0.020 | 0.61 | 0.037 | 40                      | 157       |
| B3                           | 0.289              | 3.82 | 0.06  | ..... | 0.035 | 0.023 | 0.36 | 0.239 | 87                      | 181       |
| A6                           | 0.252              | 3.89 | ..... | ..... | 0.018 | 0.021 | 0.60 | 0.249 | 92                      | 193       |
| BH                           | 0.238              | 3.78 | 0.27  | ..... | 0.010 | 0.039 | 0.63 | 0.163 | 118                     | 191       |
| C9                           | 0.192              | 3.72 | 0.07  | ..... | 0.019 | 0.023 | 0.66 | 0.218 | 67                      | 202       |
| B2                           | 0.184              | 3.75 | 0.10  | ..... | 0.029 | 0.024 | 0.66 | 0.244 | 103                     | 191       |
| Group 8, Nickel.             |                    |      |       |       |       |       |      |       |                         |           |
| DD                           | 0.392              | 3.27 | 0.08  | ..... | 0.008 | 0.025 | 0.64 | 0.300 | 50                      | 156       |
| 115                          | 0.369              | 3.14 | 0.17  | ..... | 0.012 | 0.020 | 0.65 | 0.197 | 83                      | 171       |
| A7                           | 0.367              | 3.61 | ..... | ..... | 0.013 | 0.029 | 0.65 | 0.075 | 65                      | 168       |
| D1                           | 0.356              | 3.20 | 0.11  | ..... | 0.017 | 0.038 | 0.77 | 0.221 | 91                      | 165       |
| BB                           | 0.342              | 3.35 | 0.05  | ..... | 0.011 | 0.020 | 0.71 | 0.155 | 95                      | .....     |
| Y5                           | 0.336              | 3.17 | ..... | ..... | 0.019 | 0.019 | 0.55 | 0.188 | 39                      | 190       |
| CC                           | 0.324              | 3.40 | 0.05  | ..... | 0.008 | 0.023 | 0.55 | 0.126 | 48                      | 161       |
| EEE                          | 0.322              | 3.68 | ..... | ..... | 0.012 | 0.019 | 0.53 | 0.050 | 99                      | 181       |
| A&                           | 0.318              | 3.25 | 0.13  | ..... | 0.011 | 0.013 | 0.63 | 0.310 | 58                      | 153       |
| CC                           | 0.311              | 3.18 | 0.15  | ..... | 0.032 | 0.026 | 0.74 | 0.032 | 97                      | 172       |
| B1                           | 0.299              | 3.54 | ..... | ..... | 0.034 | 0.023 | 0.70 | 0.244 | 77                      | 174       |
| B&                           | 0.276              | 3.54 | 0.07  | ..... | 0.011 | 0.031 | 0.71 | 0.175 | 67                      | 182       |
| BOX                          | 0.248              | 3.10 | 0.07  | ..... | 0.025 | 0.027 | 0.70 | 0.251 | 87                      | 172       |
| 113                          | 0.244              | 3.30 | 0.15  | ..... | 0.009 | 0.017 | 0.66 | 0.211 | 96                      | 188       |
| BO                           | 0.231              | 3.71 | 0.07  | ..... | 0.041 | 0.028 | 0.70 | 0.225 | 84                      | 199       |
| HH                           | 0.231              | 3.43 | 0.06  | ..... | 0.009 | 0.010 | 0.67 | 0.169 | 85                      | 207       |
| K                            | 0.216              | 3.50 | 0.19  | ..... | 0.025 | 0.034 | 0.54 | 0.032 | 154                     | 211       |
| 88                           | 0.193              | 3.47 | 0.05  | ..... | 0.012 | 0.028 | 0.70 | 0.155 | 83                      | 192       |
| 99                           | 0.184              | 3.34 | 0.05  | ..... | 0.011 | 0.021 | 0.70 | 0.159 | 79                      | 189       |
| X7                           | 0.176              | 3.52 | ..... | ..... | 0.036 | 0.028 | 0.39 | 0.080 | 102                     | 190       |
| CA                           | 0.168              | 3.59 | ..... | ..... | 0.009 | 0.027 | 0.38 | 0.115 | 95                      | 195       |
| D3                           | 0.164              | 3.43 | 0.09  | ..... | 0.009 | 0.029 | 0.40 | 0.177 | 97                      | 211       |
| RO                           | 0.165              | 3.24 | ..... | ..... | 0.036 | 0.036 | 0.49 | 0.052 | 96                      | 190       |
| KK                           | 0.151              | 3.46 | 0.06  | ..... | 0.008 | 0.028 | 0.53 | 0.141 | 97                      | 192       |
| 1111                         | 0.131              | 3.38 | 0.05  | ..... | 0.014 | 0.025 | 0.67 | 0.197 | 109                     | 188       |
| D6                           | 0.097              | 3.27 | ..... | ..... | 0.007 | 0.030 | 0.49 | 0.052 | 120                     | 200       |

| Mark.                   | Chemical Analysis. |      |      |       |       |       |      |       | Increased Weight in Mg. |           |
|-------------------------|--------------------|------|------|-------|-------|-------|------|-------|-------------------------|-----------|
|                         | C.                 | Ni.  | Cr.  | V.    | P.    | S.    | Mn.  | Si.   | 900° C.                 | 1,000° C. |
| Group 9, Chrome-Nickel. |                    |      |      |       |       |       |      |       |                         |           |
| CT                      | 0.498              | 3.43 | 0.30 | 0.08  | 0.008 | 0.038 | 0.57 | 0.178 | 51                      | 165       |
| AK                      | 0.469              | 2.63 | 0.61 | ..... | 0.018 | 0.012 | 0.47 | 0.272 | 68                      | 168       |
| XO                      | 0.408              | 3.35 | 0.77 | ..... | 0.008 | 0.013 | 0.45 | 0.253 | 79                      | .....     |
| SS                      | 0.402              | 3.03 | 0.37 | ..... | 0.017 | 0.023 | 0.74 | 0.202 | 58                      | 157       |
| DDD                     | 0.362              | 3.27 | 0.54 | ..... | 0.012 | 0.015 | 0.53 | 0.112 | 85                      | 188       |
| JJ                      | 0.330              | 2.92 | 0.47 | ..... | 0.023 | 0.038 | 0.63 | 0.282 | 69                      | 184       |
| CU                      | 0.295              | 3.55 | 0.22 | 0.03  | 0.009 | 0.031 | 0.62 | 0.047 | 53                      | 201       |
| N4                      | 0.276              | 2.75 | 0.36 | ..... | 0.009 | 0.019 | 0.45 | 0.235 | 92                      | 197       |
| E7                      | 0.281              | 3.27 | 0.68 | ..... | 0.039 | 0.030 | 0.30 | 0.177 | 105                     | 193       |
| VVV                     | 0.267              | 2.81 | 0.31 | ..... | 0.020 | 0.017 | 0.45 | 0.216 | 78                      | 191       |
| N3                      | 0.254              | 2.62 | 0.29 | ..... | 0.013 | 0.017 | 0.60 | 0.302 | 104                     | 199       |
| S6                      | 0.247              | 3.07 | 0.20 | ..... | 0.036 | 0.033 | 0.53 | 0.008 | 80                      | 208       |
| AM                      | 0.242              | 3.11 | 0.67 | ..... | 0.019 | 0.012 | 0.37 | 0.324 | 111                     | 176       |
| NNN                     | 0.223              | 2.78 | 0.24 | ..... | 0.029 | 0.026 | 0.54 | 0.126 | 60                      | 185       |
| LL                      | 0.220              | 2.81 | 0.65 | ..... | 0.026 | 0.040 | 0.37 | 0.179 | 98                      | 209       |
| T7                      | 0.224              | 3.33 | 0.64 | ..... | 0.035 | 0.017 | 0.50 | 0.061 | 88                      | 211       |
| KA                      | 0.129              | 3.07 | 0.39 | ..... | 0.012 | 0.029 | 0.31 | 0.100 | 110                     | 206       |
| MO                      | 0.096              | 2.75 | 0.50 | ..... | 0.016 | 0.021 | 0.89 | 0.110 | 93                      | 223       |

## Group 10, Chrome-Nickel.

|     |       |      |      |       |       |       |      |       |     |     |
|-----|-------|------|------|-------|-------|-------|------|-------|-----|-----|
| C1  | 0.439 | 3.16 | 1.12 | ..... | 0.025 | 0.027 | 0.48 | 0.230 | 42  | 179 |
| C6  | 0.402 | 3.45 | 1.20 | 0.20  | 0.017 | 0.027 | 0.74 | 0.244 | 121 | 226 |
| RRR | 0.345 | 3.34 | 1.04 | ..... | 0.024 | 0.018 | 0.47 | 0.249 | 112 | 178 |
| 11  | 0.323 | 3.40 | 1.35 | 0.03  | 0.009 | 0.018 | 0.19 | 0.126 | 110 | 220 |
| YYY | 0.312 | 3.50 | 0.99 | ..... | 0.027 | 0.017 | 0.43 | 0.206 | 74  | 187 |
| D4  | 0.298 | 3.91 | 1.42 | ..... | 0.012 | 0.028 | 0.42 | 0.197 | 66  | 195 |
| UUU | 0.229 | 3.27 | 0.94 | ..... | 0.018 | 0.016 | 0.40 | 0.216 | 58  | 209 |
| KB  | 0.197 | 3.51 | 1.84 | 0.07  | 0.034 | 0.038 | 0.22 | 0.153 | 92  | 218 |
| C3  | 0.166 | 3.52 | 1.11 | ..... | 0.023 | 0.028 | 0.41 | 0.225 | 112 | 218 |
| CV  | 0.184 | 3.26 | 1.29 | 0.03  | 0.023 | 0.029 | 0.73 | 0.145 | 92  | 245 |
| D2  | 0.090 | 2.94 | 0.85 | ..... | 0.009 | 0.038 | 0.55 | 0.139 | 108 | 244 |

## Group 11, Chrome-Nickel.

|     |       |      |      |       |       |       |      |       |     |     |
|-----|-------|------|------|-------|-------|-------|------|-------|-----|-----|
| E2  | 0.645 | 1.66 | 0.46 | 0.15  | 0.023 | 0.037 | 0.72 | 0.115 | 29  | 155 |
| A1  | 0.567 | 0.93 | 0.64 | ..... | 0.018 | 0.032 | 0.60 | 0.235 | 83  | 169 |
| E5  | 0.555 | 2.36 | 0.41 | ..... | 0.027 | 0.039 | 0.52 | 0.201 | 61  | 150 |
| H7  | 0.546 | 1.57 | 0.51 | ..... | 0.010 | 0.022 | 0.46 | 0.060 | 83  | 188 |
| E4  | 0.496 | 1.27 | 0.38 | 0.38  | 0.029 | 0.034 | 0.35 | 0.182 | 86  | 190 |
| JJJ | 0.401 | 1.16 | 0.23 | ..... | 0.011 | 0.038 | 0.50 | 0.098 | 71  | 198 |
| A7  | 0.382 | 1.60 | 0.49 | ..... | 0.004 | 0.038 | 0.59 | 0.052 | 105 | 200 |
| F   | 0.370 | 1.51 | 0.26 | ..... | 0.011 | 0.039 | 0.60 | 0.118 | 82  | 182 |
| C8  | 0.340 | 1.20 | 0.53 | ..... | 0.006 | 0.024 | 0.51 | 0.172 | 70  | 201 |
| N   | 0.326 | 0.99 | 0.11 | ..... | 0.008 | 0.047 | 0.58 | 0.042 | 95  | 190 |
| YY  | 0.298 | 1.08 | 0.18 | ..... | 0.008 | 0.035 | 0.39 | 0.070 | 110 | 214 |
| R5  | 0.274 | 1.20 | 0.41 | 0.08  | 0.007 | 0.032 | 0.56 | 0.057 | 123 | 205 |
| R4  | 0.271 | 1.25 | 0.35 | 0.96  | 0.013 | 0.038 | 0.56 | 0.115 | 77  | 205 |
| R6  | 0.258 | 1.25 | 0.37 | 0.86  | 0.007 | 0.033 | 0.57 | 0.159 | 106 | 189 |
| A6  | 0.198 | 1.77 | 0.46 | ..... | 0.007 | 0.032 | 0.40 | 0.084 | 97  | 189 |
| C7  | 0.147 | 1.28 | 0.37 | ..... | 0.005 | 0.025 | 0.34 | 0.134 | 74  | 201 |
| A1  | 0.083 | 1.51 | 0.30 | ..... | 0.004 | 0.037 | 0.44 | 0.041 | 116 | 219 |

| Mark. | Chemical Analysis. |     |     |    |    |    |     |     | Increased Weight<br>in Mg. |           |
|-------|--------------------|-----|-----|----|----|----|-----|-----|----------------------------|-----------|
|       | C.                 | Ni. | Cr. | V. | P. | S. | Mn. | Si. | 900° C.                    | 1,000° C. |

## Group 12, Chrome-Nickel.

|     |       |      |      |       |       |       |      |       |     |     |
|-----|-------|------|------|-------|-------|-------|------|-------|-----|-----|
| C2  | 0.552 | 1.53 | 1.14 | ..... | 0.020 | 0.024 | 0.41 | 0.225 | 65  | 196 |
| BY  | 0.504 | 1.57 | 1.19 | 0.03  | 0.009 | 0.032 | 0.50 | 0.180 | 109 | 183 |
| M   | 0.503 | 1.93 | 0.99 | ..... | 0.008 | 0.016 | 0.52 | 0.127 | 110 | 175 |
| GG  | 0.442 | 2.12 | 1.06 | ..... | 0.009 | 0.020 | 0.19 | 0.197 | 64  | 188 |
| S7  | 0.415 | 1.59 | 1.11 | ..... | 0.018 | 0.018 | 0.36 | 0.094 | 106 | 204 |
| E7  | 0.394 | 1.25 | 1.12 | ..... | 0.027 | 0.034 | 0.35 | 0.365 | 149 | 186 |
| K2  | 0.377 | 1.67 | 1.31 | ..... | 0.023 | 0.037 | 0.21 | 0.163 | 98  | 211 |
| D   | 0.365 | 2.04 | 0.99 | ..... | 0.008 | 0.019 | 0.15 | 0.103 | 106 | 196 |
| A8  | 0.363 | 1.55 | 0.70 | ..... | 0.004 | 0.036 | 0.53 | 0.112 | 113 | 196 |
| BT  | 0.307 | 2.03 | 1.01 | ..... | 0.032 | 0.034 | 0.53 | 0.150 | 98  | 224 |
| A4  | 0.308 | 1.35 | 0.72 | ..... | 0.005 | 0.036 | 0.67 | 0.070 | 89  | 199 |
| C4  | 0.251 | 2.33 | 1.24 | 0.06  | 0.032 | 0.028 | 0.43 | 0.225 | 128 | 218 |
| FF  | 0.226 | 2.06 | 0.97 | ..... | 0.014 | 0.024 | 0.11 | 0.075 | 89  | 228 |
| M6  | 0.228 | 1.05 | 0.99 | 0.22  | 0.023 | 0.025 | 0.32 | 0.149 | 124 | 229 |
| S3  | 0.213 | 1.79 | 1.05 | ..... | 0.016 | 0.020 | 0.42 | 0.092 | 114 | 207 |
| CH  | 0.197 | 1.44 | 0.79 | ..... | 0.029 | 0.033 | 0.23 | 0.245 | 87  | 215 |
| FFF | 0.186 | 2.03 | 0.66 | ..... | 0.012 | 0.015 | 0.53 | 0.122 | 62  | 191 |
| K8  | 0.178 | 1.28 | 1.59 | ..... | 0.022 | 0.044 | 0.27 | 0.053 | 110 | 218 |

## Group 13, Nickel.

|    |       |      |       |       |       |       |      |       |     |     |
|----|-------|------|-------|-------|-------|-------|------|-------|-----|-----|
| YO | 0.660 | 0.25 | ..... | ..... | 0.027 | 0.019 | 0.43 | 0.235 | 90  | 146 |
| BX | 0.454 | 0.27 | ..... | ..... | 0.022 | 0.033 | 0.59 | 0.170 | 87  | 173 |
| A  | 0.220 | 0.23 | ..... | ..... | 0.006 | 0.039 | 0.42 | 0.056 | 94  | 231 |
| T9 | 0.190 | 0.22 | ..... | ..... | 0.028 | 0.020 | 0.45 | 0.042 | 102 | 221 |

## Group 14, Chrome-Nickel.

|     |       |      |      |       |       |       |      |       |     |     |
|-----|-------|------|------|-------|-------|-------|------|-------|-----|-----|
| K7  | 0.559 | 0.20 | 0.07 | ..... | 0.012 | 0.031 | 0.37 | 0.202 | 72  | 179 |
| CD  | 0.530 | 0.26 | 0.11 | ..... | 0.036 | 0.029 | 0.69 | 0.140 | 77  | 173 |
| E8  | 0.515 | 0.56 | 0.14 | ..... | 0.034 | 0.037 | 0.48 | 0.159 | 91  | 161 |
| K4  | 0.443 | 0.27 | 0.22 | ..... | 0.032 | 0.028 | 1.57 | 0.115 | 81  | 183 |
| KKK | 0.428 | 0.53 | 0.17 | ..... | 0.012 | 0.030 | 0.49 | 0.075 | 92  | 172 |
| K1  | 0.373 | 0.40 | 0.18 | ..... | 0.017 | 0.032 | 0.48 | 0.230 | 85  | 186 |
| CP  | 0.300 | 0.25 | 0.10 | ..... | 0.015 | 0.025 | 0.62 | 0.112 | 104 | 209 |
| C&  | 0.231 | 0.30 | 0.06 | ..... | 0.012 | 0.034 | 0.60 | 0.169 | 84  | 195 |
| KC  | 0.210 | 0.27 | 0.19 | ..... | 0.048 | 0.046 | 0.47 | 0.244 | 150 | 203 |
| U8  | 0.201 | 0.50 | 0.20 | ..... | 0.009 | 0.058 | 0.47 | 0.004 | 114 | 207 |
| L   | 0.170 | 0.52 | 0.13 | ..... | 0.008 | 0.042 | 0.52 | 0.018 | 144 | 255 |
| KD  | 0.150 | 0.16 | 0.06 | ..... | 0.015 | 0.039 | 0.49 | 0.225 | 84  | 207 |
| CI  | 0.127 | 0.18 | 0.07 | ..... | 0.070 | 0.072 | 0.60 | 0.125 | 108 | 217 |

## Group 15, Chrome-Nickel.

|     |       |      |      |       |       |       |      |       |    |     |
|-----|-------|------|------|-------|-------|-------|------|-------|----|-----|
| HHH | 0.703 | 0.24 | 0.47 | ..... | 0.011 | 0.015 | 0.54 | 0.094 | 80 | 177 |
|-----|-------|------|------|-------|-------|-------|------|-------|----|-----|

| Mark. | Chemical Analysis. |     |     |    |    |    |     |     | Increased Weight in Mg. |           |
|-------|--------------------|-----|-----|----|----|----|-----|-----|-------------------------|-----------|
|       | C.                 | Ni. | Cr. | V. | P. | S. | Mn. | Si. | 900° C.                 | 1,000° C. |

**Group 16, Carbon.**

|     |       |       |       |       |       |       |      |       |     |       |
|-----|-------|-------|-------|-------|-------|-------|------|-------|-----|-------|
| d5  | 1.21  | ..... | ..... | ..... | 0.007 | 0.032 | 0.32 | 0.163 | 72  | 73    |
| A4  | 1.03  | ..... | ..... | ..... | 0.011 | 0.032 | 0.37 | 0.141 | 55  | 79    |
| BM  | 0.667 | ..... | ..... | ..... | 0.009 | 0.018 | 0.77 | 0.168 | 59  | 152   |
| CE  | 0.593 | 0.06  | ..... | ..... | 0.050 | 0.029 | 0.65 | 0.315 | 67  | 149   |
| AH  | 0.447 | 0.11  | ..... | ..... | 0.014 | 0.017 | 0.60 | 0.206 | 102 | 200   |
| E   | 0.414 | ..... | ..... | ..... | 0.014 | 0.038 | 0.51 | 0.052 | 78  | 194   |
| QQ  | 0.389 | ..... | ..... | ..... | 0.012 | 0.032 | 0.57 | 0.159 | 85  | 216   |
| X6  | 0.341 | ..... | ..... | ..... | 0.047 | 0.025 | 1.61 | 0.009 | 86  | 223   |
| B8  | 0.344 | ..... | 0.06  | ..... | 0.014 | 0.029 | 0.54 | 0.030 | 93  | 217   |
| X1  | 0.305 | ..... | ..... | ..... | 0.041 | 0.018 | 1.61 | 0.014 | 96  | 213   |
| H8  | 0.300 | ..... | 0.04  | ..... | 0.039 | 0.024 | 1.60 | 0.098 | 126 | 225   |
| EE  | 0.294 | ..... | 0.04  | ..... | 0.014 | 0.037 | 0.42 | 0.018 | 112 | 208   |
| LLL | 0.294 | ..... | ..... | ..... | 0.023 | 0.040 | 0.44 | 0.037 | 94  | 190   |
| U6  | 0.283 | ..... | 0.08  | ..... | 0.016 | 0.018 | 1.60 | 0.023 | 109 | 201   |
| T3  | 0.276 | ..... | 0.05  | ..... | 0.058 | 0.029 | 1.35 | 0.173 | 86  | 201   |
| D   | 0.267 | ..... | ..... | ..... | 0.009 | 0.031 | 0.37 | 0.022 | 103 | 200   |
| B9  | 0.244 | ..... | ..... | ..... | 0.104 | 0.053 | 0.52 | 0.056 | 94  | 204   |
| Y7  | 0.240 | ..... | 0.05  | ..... | 0.018 | 0.018 | 0.38 | 0.056 | 104 | 188   |
| AX  | 0.228 | ..... | ..... | ..... | 0.077 | 0.072 | 0.80 | 0.018 | 89  | 209   |
| Y1  | 0.216 | ..... | ..... | ..... | 0.013 | 0.019 | 0.30 | 0.084 | 113 | ..... |
| X4  | 0.219 | ..... | ..... | ..... | 0.027 | 0.031 | 0.46 | 0.005 | 121 | 242   |
| U7  | 0.217 | ..... | 0.06  | ..... | 0.029 | 0.022 | 0.72 | 0.051 | 97  | 229   |
| AU  | 0.205 | ..... | ..... | ..... | 0.010 | 0.038 | 0.54 | 0.014 | 105 | 216   |
| X5  | 0.196 | ..... | ..... | ..... | 0.023 | 0.027 | 0.71 | 0.008 | 116 | 220   |
| B7  | 0.202 | ..... | ..... | ..... | 0.010 | 0.023 | 0.51 | 0.030 | 113 | 218   |
| M8  | 0.195 | ..... | 0.06  | ..... | 0.016 | 0.046 | 0.59 | 0.225 | 105 | 207   |
| X3  | 0.186 | ..... | ..... | ..... | 0.016 | 0.022 | 0.47 | 0.009 | 106 | 210   |
| BV  | 0.166 | 0.06  | 0.04  | ..... | 0.049 | 0.049 | 0.63 | 0.042 | 103 | 235   |
| U5  | 0.167 | ..... | ..... | ..... | 0.020 | 0.021 | 0.44 | 0.005 | 110 | 213   |
| E1  | 0.146 | ..... | ..... | ..... | 0.018 | 0.044 | 0.87 | 0.057 | 104 | 251   |
| M2  | 0.139 | ..... | ..... | 0.07  | 0.013 | 0.033 | 0.16 | 0.225 | 130 | 227   |
| TTT | 0.111 | ..... | ..... | ..... | 0.018 | 0.135 | 0.59 | 0.025 | 115 | 227   |
| T1  | 0.077 | ..... | 0.07  | ..... | 0.013 | 0.019 | 0.60 | 0.075 | 91  | 235   |
| OOO | 0.022 | ..... | 0.06  | ..... | 0.012 | 0.022 | 0.10 | 0.025 | 95  | 215   |

**Group 17, Chrome-Vanadium.**

|     |       |       |      |      |       |       |      |       |     |     |
|-----|-------|-------|------|------|-------|-------|------|-------|-----|-----|
| H5  | 0.676 | ..... | 0.75 | 0.11 | 0.014 | 0.033 | 0.67 | 0.197 | 108 | 170 |
| V   | 0.569 | ..... | 0.69 | 0.22 | 0.008 | 0.019 | 0.37 | 0.202 | 84  | 191 |
| S2  | 0.479 | ..... | 0.71 | 0.18 | 0.009 | 0.027 | 0.79 | 0.173 | 120 | 231 |
| G   | 0.318 | 0.12  | 0.74 | 0.21 | 0.015 | 0.023 | 0.42 | 0.165 | 117 | 221 |
| CX  | 0.266 | 0.24  | 0.62 | 0.17 | 0.032 | 0.037 | 0.26 | 0.108 | 129 | 222 |
| VV  | 0.129 | ..... | 0.33 | 0.10 | 0.008 | 0.030 | 0.33 | 0.108 | 116 | 214 |
| BBB | 0.127 | ..... | 0.73 | 0.16 | 0.012 | 0.018 | 0.46 | 0.051 | 142 | 247 |

| Mark. | Chemical Analysis. |     |     |    |    |    |     |     | Increased Weight in Mg. |           |
|-------|--------------------|-----|-----|----|----|----|-----|-----|-------------------------|-----------|
|       | C.                 | Nl. | Cr. | V. | P. | S. | Mn. | Si. | 900° C.                 | 1,000° C. |

## Group 18. Chrome-Vanadium.

|     |       |       |      |      |       |       |      |       |     |     |
|-----|-------|-------|------|------|-------|-------|------|-------|-----|-----|
| B4  | 1.06  | ..... | 0.95 | 0.10 | 0.022 | 0.023 | 0.36 | 0.220 | 94  | 143 |
| X2  | 0.882 | ..... | 1.14 | 0.23 | 0.041 | 0.022 | 0.50 | 0.094 | 109 | 196 |
| M3  | 0.708 | ..... | 0.94 | 0.21 | 0.026 | 0.022 | 0.47 | 0.062 | 111 | 190 |
| M5  | 0.617 | ..... | 1.19 | 0.23 | 0.031 | 0.025 | 0.76 | 0.153 | 90  | 207 |
| J   | 0.612 | ..... | 0.82 | 0.19 | 0.009 | 0.021 | 0.39 | 0.145 | 85  | 210 |
| AO  | 0.515 | ..... | 1.01 | 0.19 | 0.006 | 0.017 | 0.70 | 0.286 | 123 | 200 |
| 4   | 0.520 | ..... | 1.16 | 0.15 | 0.011 | 0.027 | 0.47 | 0.162 | 108 | 220 |
| XX  | 0.491 | ..... | 1.04 | 0.09 | 0.011 | 0.020 | 0.92 | 0.155 | 110 | 206 |
| Y   | 0.474 | 0.10  | 1.19 | 0.18 | 0.009 | 0.014 | 0.80 | 0.159 | 134 | 244 |
| I   | 0.457 | ..... | 1.17 | 0.14 | 0.009 | 0.025 | 0.48 | 0.198 | 113 | 236 |
| B5  | 0.453 | ..... | 1.04 | 0.18 | 0.025 | 0.026 | 0.98 | 0.296 | 128 | 233 |
| CO  | 0.406 | 0.34  | 1.23 | 0.20 | 0.050 | 0.035 | 0.32 | 0.174 | 126 | 217 |
| O   | 0.411 | ..... | 1.05 | 0.10 | 0.034 | 0.027 | 0.66 | 0.136 | 114 | 219 |
| &   | 0.397 | 0.13  | 1.26 | 0.19 | 0.008 | 0.016 | 0.82 | 0.169 | 126 | 257 |
| 3   | 0.374 | ..... | 1.04 | 0.15 | 0.009 | 0.029 | 0.62 | 0.148 | 145 | 230 |
| Z   | 0.339 | 0.12  | 0.97 | 0.19 | 0.008 | 0.013 | 0.48 | 0.145 | 137 | 231 |
| UU  | 0.338 | ..... | 1.00 | 0.13 | 0.011 | 0.038 | 0.57 | 0.094 | 118 | 230 |
| Y4  | 0.320 | ..... | 0.94 | 0.19 | 0.020 | 0.027 | 0.62 | 0.094 | 120 | 230 |
| AAA | 0.310 | ..... | 0.86 | 0.27 | 0.012 | 0.021 | 0.83 | 0.085 | 129 | 230 |
| C5  | 0.204 | ..... | 1.03 | 0.15 | 0.012 | 0.027 | 0.52 | 0.244 | 157 | 237 |
| S   | 0.161 | 0.09  | 0.74 | 0.19 | 0.012 | 0.025 | 0.32 | 0.178 | 142 | 247 |

## Group 19, Chrome-Vanadium.

|    |       |       |      |      |       |       |      |       |     |     |
|----|-------|-------|------|------|-------|-------|------|-------|-----|-----|
| K6 | 0.754 | ..... | 1.95 | 0.51 | 0.034 | 0.023 | 0.23 | 0.316 | 127 | 212 |
| K5 | 0.382 | 0.26  | 2.09 | 0.06 | 0.010 | 0.037 | 0.19 | 0.187 | 121 | 227 |

## Group 20, Chrome.

|    |       |       |      |       |       |       |      |       |     |     |
|----|-------|-------|------|-------|-------|-------|------|-------|-----|-----|
| 80 | 0.957 | 0.22  | 1.23 | ..... | 0.022 | 0.016 | 0.26 | 0.188 | 103 | 150 |
| 85 | 0.906 | ..... | 0.92 | ..... | 0.014 | 0.028 | 0.35 | 0.089 | 79  | 141 |

## Group 21, Chrome.

|    |       |       |      |       |       |       |      |       |    |     |
|----|-------|-------|------|-------|-------|-------|------|-------|----|-----|
| U1 | 0.673 | ..... | 0.11 | ..... | 0.020 | 0.009 | 0.66 | 0.267 | 76 | 164 |
| U2 | 0.490 | ..... | 0.12 | ..... | 0.020 | 0.010 | 0.44 | 0.310 | 94 | 192 |

## Group 22, Chrome-Silicon.

|    |       |       |      |       |       |       |      |       |     |     |
|----|-------|-------|------|-------|-------|-------|------|-------|-----|-----|
| HI | 0.402 | ..... | 0.92 | ..... | 0.007 | 0.017 | 0.78 | 0.537 | 108 | 195 |
|----|-------|-------|------|-------|-------|-------|------|-------|-----|-----|

## Group 23, Silicon.

|     |       |       |       |       |       |       |      |       |    |       |
|-----|-------|-------|-------|-------|-------|-------|------|-------|----|-------|
| Q   | 0.672 | ..... | ..... | ..... | 0.047 | 0.044 | 0.48 | 1.18  | 18 | 101   |
| AD  | 0.617 | 0.14  | ..... | ..... | 0.013 | 0.009 | 0.54 | 1.60  | 14 | 109   |
| QQQ | 0.494 | ..... | 0.05  | ..... | 0.044 | 0.036 | 1.18 | 0.677 | 65 | 137   |
| R   | 0.365 | ..... | ..... | ..... | 0.025 | 0.035 | 0.57 | 1.27  | 77 | 49    |
| RS  | 0.371 | 0.21  | ..... | ..... | 0.063 | 0.042 | 0.57 | 2.16  | 66 | 107   |
| B6  | 0.307 | 0.53  | ..... | ..... | 0.049 | 0.026 | 0.48 | 2.39  | 79 | 125   |
| B   | 0.225 | ..... | 0.05  | ..... | 0.028 | 0.036 | 0.54 | 0.972 | 70 | 126   |
| 2   | 0.222 | ..... | 0.02  | ..... | 0.009 | 0.047 | 0.58 | 0.996 | 82 | ..... |

In order to correlate the value of the various elements in their carburizing effect a mathematical investigation was undertaken. From each steel an equation can be formed connecting the increased weight with the percentage of the various elements present. This will give us as many equations as we have steels, and the problem then resolves itself into an equalization of the errors of observation, analysis and weight entering into each equation by a consideration of the remaining ones. This can be done by the method of least squares. All the elements were first considered, and much time was spent in solving this problem. This proved a mathematical success, but a flat failure from a practical standpoint.

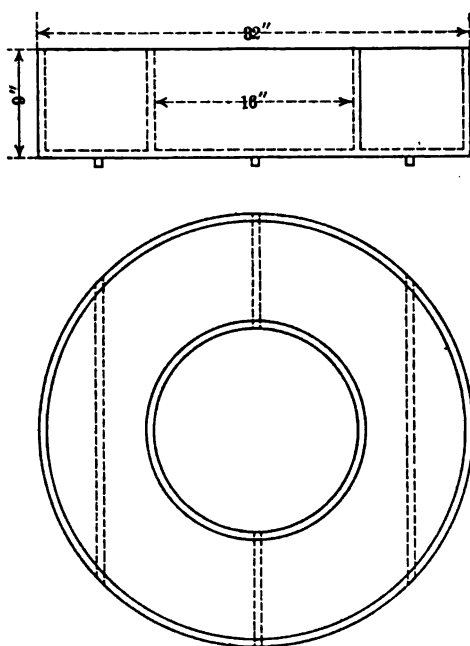


FIG. 1.—CARBURIZING BOX.

By the method of least squares a problem containing more equations than unknowns is solved by reducing the excess equations to a number equal to the unknown quantities. These final equations are known as normal equations; they are solved by the ordinary processes of algebra. In this case they were solved by the method of determinants. There are many difficulties in the way of the solution of such a problem, some of which are as follows:

- (a) The correct formation of the original equations.
- (b) The presence of elements occurring in nearly constant amounts.
- (c) The presence of elements having little or no influence on the final result.

The formation of the original equation is the most important source of error. For example, the amount of carbon absorbed may not be a straight-line function of the percentage of some one element. Their relationship may be expressed by a curve or a broken line or a combination of the two. Again, element *A* in the absence of element *B* may be a straight-line function throughout its range, while in the presence of *B* it may not be. As an example of this it might easily be conceived that chromium existing as a carbide of chromium would have a different effect from chromium in solution with the iron. In all the mathematical work undertaken in this investigation it was assumed that the relations were represented by straight-line functions. Apparently some of the results indicate that this is a source of error.

In a solution of a problem by the method of least squares the final answer obtained is the most probable considering all the variables. Manifestly an element having no effect on the final result or one occurring in constant quantity should not have the errors of measurement of the other variables distributed over it. This is one source of error in the present problem. For this reason after the failure of the first solution sulphur, manganese, phosphorus, and silicon were left out of the calculation and the high-silicon steels were not used in further calculation involving more than two variables.

An equation containing three unknowns was formed from steels of groups 1, 2, 3, 4, 7, 8, 13, 16, omitting those containing any appreciable amounts of chromium and using high-temperature weight only. This equation was placed in the intercept form thus:

$$\frac{C}{a} + \frac{N}{b} + \frac{W}{d} = 1 \quad (1)$$

in which *C*, *N*, and *W* represent the percentage of carbon, nickel, and increase in weight, respectively, while *a*, *b*, and *d* are the intercepts of the plane representing the equation upon the corresponding axes. The 76 separate equations thus formed were reduced to four normal equations, which, in turn, were solved, giving the following values:

$$a = \frac{C^2 N^2 W^2 + 2 (CN) (NW) (CW) - (CW)^2 N^2 - (CN)^2 W^2 - (NW)^2 C^2}{CN^2 W^2 + (CN) (NW) W + N (NW) (CW) - W N^2 (CW) - (CN) N W^2 - C (NW)^2}$$

$$b = \frac{C^2 N^2 W^2 + 2 (CN) (NW) (CW) - (CW)^2 N^2 - (CN)^2 W^2 - (NW)^2 C^2}{C^2 N W^2 + C (NW) (CW) + (CW) (CN) W - N (CW)^2 - C W^2 (CN) - C^2 W (NW)}$$

$$c = \frac{C^2 N^2 W^2 + 2 (CN) (NW) (CW) - (CW)^2 N^2 - (CN)^2 W^2 - (NW)^2 C^2}{C^2 N^2 W + N (CN) (CW) + C (CN) (WN) - CN^2 (CW) - (CN)^2 W - C^2 N (NW)}$$



In the above values of a, b, and c, the letters C, N, and W represent the summation of the carbon, nickel, and weight values of the total number of steels and not the values of the single steels as is represented in equation (1).

The equation determined from the above values is as follows:

$$\frac{\text{Carbon}}{1.13} + \frac{\text{Nickel}}{39.5} + \frac{\text{Weight}}{265} = 1 \quad (2)$$

These values are very reasonable and have the following meaning: 1.13 per cent. of carbon will reduce the efficiency of carbon absorption the same amount as 39.5 per cent. of nickel, or, stated in a better form, 0.01 per cent. carbon is equivalent to 0.35 per cent. nickel. To make use of it in a practical problem a 3.5 per cent. nickel steel of 0.20 per cent. carbon will absorb carbon as rapidly and in the same amounts as a 0.30 per cent. carbon steel without nickel.

An attempt was then made to form an equation connecting carbon, nickel, and chrome with weight by using all the analyses except groups 22 and 23. The equations so determined were as follows:

For 900°:

$$\frac{\text{Carbon}}{0.56} + \frac{\text{Nickel}}{6.85} - \frac{\text{Chrome}}{53} + \frac{\text{Weight}}{100} = 1 \quad (3)$$

For 1,000°:

$$\frac{\text{Carbon}}{0.56} + \frac{\text{Nickel}}{6.95} - \frac{\text{Chrome}}{30} + \frac{\text{Weight}}{199} = 1 \quad (4)$$

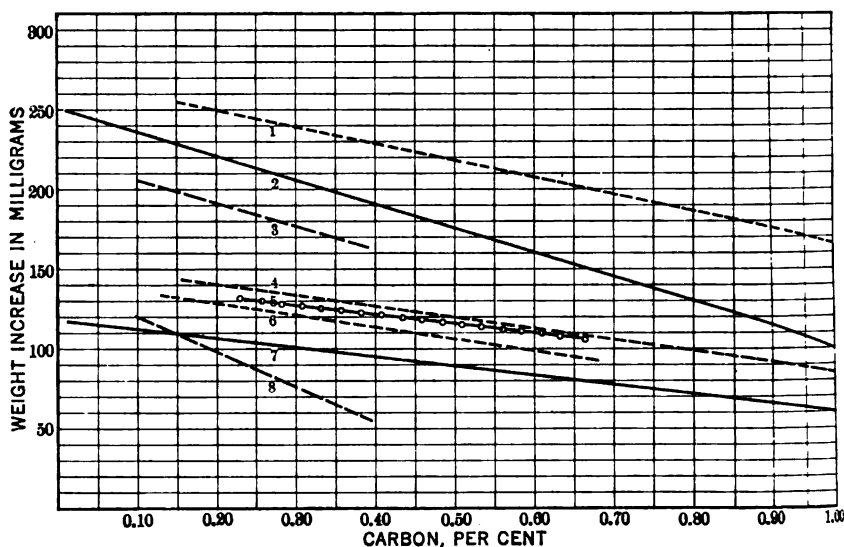
These are interesting; but while mathematically correct they are, from a practical standpoint, hard to interpret. They would indicate, for example, that a pure iron would absorb 199 mg. of carbon at 1,000° in 10 hours, and 100 mg. at 900°; as a matter of fact this is too low a value.

Equations were then worked out for the different alloy groups, using two unknowns, carbon and weight, and assuming the amounts of alloys to be constants. These results are plotted in Figs. 2 and 3, which are nearly self-explanatory.

Consider Fig. 2: Line 1 is the equation of group 18, the steels of which have an average chromium content of 1.04 per cent., and a vanadium content of 0.18 per cent. Line 2 is the equation of group

16. Line 3 of group 8, with an average nickel content of 3.38 per cent. (chrome 0.09 per cent.). Line 5 is group 23, with an average silicon content of 1.65 per cent. (Omit R.) It will be noted that the slope of the lines (except for silicon) is practically the same. In effect this means that the same increase in carbon in the original steels will lower the absorption the same amount, whether the steel be plain carbon, chrome vanadium, or nickel.

Consider a 0.20 per cent. carbon steel: 1.00 per cent. chromium and 0.18 per cent. vanadium increase the absorption rate about 13 per cent. over a plain carbon steel, while 3.38 per cent. nickel decreases



1. Chrome-Vanadium. Carburized at 1,000° C.
2. Carbon. Carburized at 1,000° C.
3. Nickel. Carburized at 1,000° C.
4. High Chrome-Vanadium. Carburized at 900° C.
5. Silicon. Carburized at 1,000° C.
6. Low Chrome-Vanadium. Carburized at 900° C.
7. Carbon. Carburized at 900° C.
8. Nickel. Carburized at 900° C.

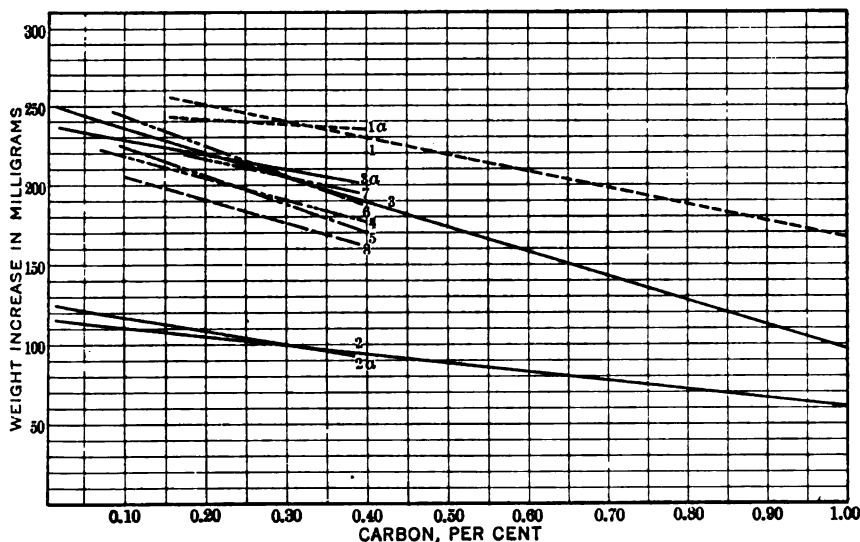
FIG. 2.—RESULTS OF CARBURIZING VARIOUS STEELS AT DIFFERENT TEMPERATURES.

this rate about the same amount; 1.65 per cent. silicon decreases it about 40 per cent.

Lines 4, 7, and 8 represent the same groups of steels as lines 1, 2, and 3, but carburized at 900°. Line 6 represents group 17, with an average chrome content of 0.62 per cent. and 0.16 per cent. vanadium.

It will be noted that with the low temperature an increase in carbon in the original steel decreases the rate of absorption more rapidly than at the high temperature.

In Fig. 3 some of the above lines are repeated and there are added lines for the chrome-nickel steels. Lines 1a and 3a were developed from the same groups of steels as lines 1 and 3, using, however, only those steels containing less than 0.40 per cent. carbon. The changed slope of these lines indicates that for a low carbon content originally in the steel, an increase in it is of less importance in influencing the



1. Chrome-Vanadium (Cr = 1.04, V = 0.18 average). All Carbons.
- 1a. Chrome-Vanadium (Cr = 0.98, V = 0.18 average). Carbon < 0.40 per cent.
3. Carbon. All Carbons.
- 3a. Carbon. Carbon < 0.40 per cent.
4. Chrome-Nickel (Cr = 0.38, Ni = 1.39 average).
5. Chrome-Nickel (Cr = 0.46, Ni = 3.03 average).
6. Chrome-Nickel (Cr = 1.20, Ni = 3.39 average).
7. Chrome-Nickel (Cr = 1.04, Ni = 1.70 average).
8. Nickel (Cr = 0.09, Ni = 3.38 average).
2. Carbon. All Carbons. Carburized at 900° C.
- 2a. Carbon. Carbon < 0.40 per cent. Carburized at 900° C.

FIG. 3.—RESULTS OF CARBURIZING VARIOUS STEELS AT 1,000° C.

rate of carburization than for a high initial content. It also indicates the probability of the carbon-weight equation being a curve. Line 4 represents group 11; line 5, group 9; line 6, group 10; line 7, group 12; line 8, group 8.

In Fig. 4 are plotted two manganese lines developed from steels X6, X1, H8, U6, T3, Y7, AX, X4, U7, AU, X5, B7, M8, X3, and M2. A correction was first made on these steels for carbon contents by reducing all to 0.20 per cent. carbon. At the lower temperature

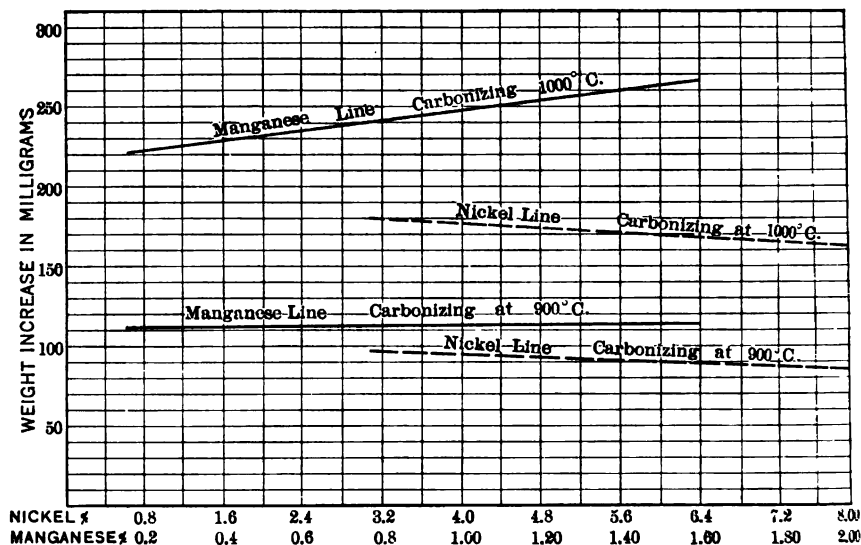


FIG. 4.—EFFECT OF MANGANESE AND NICKEL ON THE ABSORPTION OF CARBON BY STEEL.

manganese, within the range taken, apparently has no effect, while at the higher temperature it increases the carbon absorption.

In a similar manner nickel lines were plotted using steels U4, MMM, B3, CC°, B1.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Dec. 1, 1913. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross references in both volumes).

## Note on the Utilization of the Waste Heat of Regenerative Furnaces.

BY GEORGE C. STONE, NEW YORK, N. Y.

(New York Meeting, October, 1913.)

THE stack gases from regenerative furnaces are very seldom utilized for the production of steam. If the temperature of the gases is not higher than 300° C. (572° F.) there is no economy in their use for this purpose, as the amount of available heat is very small and the temperature is so little above that of the steam that the interchange is too slow. With higher temperatures of the waste gases, however, good results can be obtained.

At the plant of the New Jersey Zinc Co. (of Pa.) at Palmerton there are a number of return tubular boilers, each 6 ft. in diameter and 20 ft. long, with 96 3.5-in. tubes, which are heated by the waste gases from the spelter furnaces. These furnaces have continuous regenerators heating the air only and the stack gases reach the boilers at a temperature of about 450°. The gas producers for one of these furnaces require 14 tons of anthracite (a mixture of Nos. 2 and 3 buckwheat), and the waste heat from the furnace gives a little more than 42 h.p. in steam.

The boilers are not well adapted for the purpose, as they are much too large for the amount of heat going to them and the area of the tubes is not sufficient to take the gas from two furnaces without causing an objectionable amount of back pressure. The plant was built without any idea of using waste-heat boilers, and it was impossible to place the latter as close to the furnaces as they should be. Furnace and boiler are connected by an underground brick flue in which the temperature of the gas drops about 100°, losing 40 per cent. of its available heat. If the boilers were close to the furnaces the horse power of each would be 70 instead of 42.

Even under these unfavorable conditions the boilers have been very advantageous, as one boiler easily supplies the steam necessary for two batteries of producers.

With such low gas temperatures the heating surface of the boilers is, of course, not as efficient and the flue areas need to be considerably larger than for coal firing.

We have found that under our conditions with gases at  $450^{\circ}$  about 3 h.p. can be obtained for each ton of coal gasified, and that this is increased or decreased by 1 h.p. for a variation of  $50^{\circ}$  in the temperature of the gas entering the boiler setting. In Germany similar furnaces fired with gas from bituminous coal have given rather better results, as they were equipped with especially designed water-tube boilers. Both here and in Germany the use of the boilers has had no visible effect on the working of the furnaces.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author.

## The Disposition of Natural Resources.

BY GEORGE OTIS SMITH,\* WASHINGTON, D. C.

(New York Meeting, February, 1914.)

IN the utilization of natural resources owner, operator, and consumer should share the attendant benefits. Development needs to be planned under terms recognizing fully the interests of all concerned, for any undue advantage given to any one of these participants is apt to involve even greater and disproportionate injury to one or both of the others. For this reason it is well to preface any consideration of needed reforms in legislation affecting the disposition of public land with a survey of certain fundamental principles that determine the general conditions of all land transfers preliminary to development, utilization, and production.

The disposition of any undeveloped natural resource, whether timber, oil, coal, or water power, as a transaction to which land owner and prospective developer are parties, must be based in theory upon a division of expected returns. Whatever the terms of such disposition, neither party can reasonably ask for anything other than an equitable division of the returns. Under this analysis three and only three questions need to be discussed; namely, what are those profits, how is this division to be accomplished, and what is the equitable basis of division?

The answer to the third question should probably be found by applying to the problem the principles of theoretical sociology, and the question need not be mentioned further at this time, inasmuch as it does not involve the practical considerations to be kept in mind in connection with the other questions, which are concerned with only the measure of returns and their division. That is to say, whether the land owner's equity is to be stated as 95 per cent. or as 5 per cent. of the profits attending the development of the particular resource, no change would be necessary in the method to be adopted of arriving at the closest approximation of the prospective total profit.

If on this basis we now compare the two methods of disposing of

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\* Director, U. S. Geological Survey.

land valuable for its natural resources, sale and lease, we shall discover a somewhat regular variation in the degree of approach to the ideal determination of actual profits and accomplishment of their definite division. The sale of an undeveloped resource is predicated upon an advance estimate of its prospective value for purposes of development, and whatever the theory of division of its appraised value between the land owner and the operator, there will exist a certain element of risk which necessarily involves the possibility of disproportionate profit or loss to either party and which naturally will be discounted by both. We must recognize that the risk thus created becomes a legitimate if not absolutely necessary basis for an additional item of cost in operation and therefore will tend to increase both cost and selling price; so that if at this point there is introduced the third party to all such transactions, namely, the ultimate consumer, we discover who pays the carrying charge of this risk. This added item of cost may appear in the preliminary financing in the form of a larger interest rate offered to the bondholder, or of a larger discount given to the underwriter, or of a larger dividend promised to the stockholder, or in all these combined.

The uncertainty in the valuation of undeveloped resources may be illustrated by citing that of coal estimates in unexplored territory, it being a common experience of engineers either to overestimate or to underestimate the tonnage, even after preliminary drilling of the tract under consideration.<sup>1</sup> As a means of obviating this uncertainty so far as the amount of payment to the land owner by the operator is concerned and of permitting a more equitable sharing of the attendant risk, the advantage of lease over sale becomes apparent. In timber lands the benefits of operating under lease are of similar nature.

The charge paid by the operator to the land owner under leasehold may be figured at either a fixed or a variable rate. If fixed, the charge may be either one based upon the area of the land involved, in which case it is termed rent when paid periodically or bonus when paid in a lump sum, or one determined by the quantity of the product of the land, in which case it is termed royalty; or the compensation may be fixed by a combination of the two methods. Rent and bonus are in a measure unfair, or at least less equitable, in that they involve no direct account of the extent of actual use, while, on the other hand, royalty is dangerous in that it sometimes places a premium on speculative non-development or non-use in furtherance of

<sup>1</sup> The difficulties attending even the most painstaking efforts to estimate value or predict profits are best set forth in the contribution of Dr. Chance, *Valuation of Coal Land*, at the Butte meeting of this Institute, *Bulletin* No. 79, July, 1913, pp. 1315 to 1341.



monopolization. A combination of the two becomes advantageous, wherein the rent is made a penalty for non-use but is remitted whenever an equivalent royalty is being paid.

Royalty, expressed as so many cents or dollars per unit of the product, fails to provide the proper division of profit in that it neglects full consideration of the varying value of that product. To conform to such variation with either time or place the royalty itself should be variable, and it may be made so by a variation in terms whereby the royalty varies, for instance, with stage of development and thus indirectly and somewhat indefinitely with cost of operation, an arbitrary method of securing a definite sharing of the expected profits; or the rate may be made to vary with market price of product, as in iron ore leases, wherein there is a fixed basal royalty with an increment dependent upon the current market price of ore. Or, better, the variation may be made to coincide automatically with the changing value of the product by making the royalty one in kind, as is the common practice in petroleum leases, where the royalty is a stated fraction of the output. Yet even this better form of variable royalty itself falls short of the ideal by its lack of consideration of the important element of cost of operation, although of course it takes full account of the varying selling price. If these methods of varying the royalty with changing cost and price are combined a nearer approach to the ideal is attained, as, for instance, if the fraction expressing the royalty should be decreased as cost goes up or as gross receipts go down. An illustration of this may be seen in the advantages that would accrue in the case of an oil pool having a steadily decreasing yield, where the royalty fraction should be proportionately decreased, thus affording the operator a continuing profit—sufficient to warrant his continued pumping rather than forcing him to abandon the field. On the side of the land owner, receipts would continue over a longer period and aggregate a much larger amount, even if the royalty rate was successively decreased from  $\frac{1}{4}$  to  $\frac{1}{8}$  to  $\frac{1}{16}$  to  $\frac{1}{32}$  to  $\frac{1}{64}$  or even to  $\frac{1}{128}$ . Even more important would be the public advantage of obtaining from the pool a longer continued and larger aggregate production. Such a form of royalty would therefore be most conducive to conservation, in the benefits of which land owner, operator, and consumer would all share.

All these variations in the terms of the leasehold are simply methods of attaining a division of profit between owner and operator; that is, they have one and the same object: namely, the equitable division of the value of a resource as it is being developed. They all fail, however, of attaining their object in whatever degree they neg-

lect to take into account all the elements that determine and limit the ultimate profits: namely, varying cost, varying output, and varying price. Commonly at least one of these factors is either omitted or at best only roughly estimated in advance. In this way the division actually becomes more or less a division of gross receipts, so that it logically follows that a better result should be secured directly by the division of net returns.

Under a lease of this ideal type the return to the land owner would be, not a royalty either fixed in amount or even variable with both quantity and value of product, but instead a royalty defined in terms of a fractional interest on the part of the land owner in the net returns of the operation. This, in short, would be a partnership similar to cropping on shares by a farm tenant. If the operation produced negative results the operator, as the one more directly responsible, should probably bear the whole monetary loss, the land owner on his side having lost his share in a possible value of the resource under other management. It would seem also to follow that in this type of lease the fixing of a time limit would become unnecessary. Changing conditions, whether physical or social, need be neither predicted nor discounted to preserve the equities of either party, so that the lease could be indeterminate in form, its life being dependent upon only the permanence of the resource or of the market for the product.

Two objections to the practicability of this method will at once be suggested. First, the difficulty in the land owner controlling the efficiency and economy of the operation. He has, however, two means of influence: the one direct, namely, his choice of the lessee, and the other indirect, namely, the fact that the owner's returns and the operator's returns will be proportionate, so that it is to the operator's interest, as well as to the owner's interest, to obtain the largest possible net returns. The second objection, which has a larger basis in fact, is the difficulty of insuring both an honest and an accurate accounting.<sup>2</sup> Here, however, the only answer is one based upon an optimistic outlook on present tendencies in business. The trend is unmistakably toward uniform and public accounting. The requirement of open accounts in which well-recognized methods of accounting must be adopted will prevent in large measure not only any misrepresentation to the land owner but also—what is equally important—the imposing on the consumer of a price involving an over-

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<sup>2</sup> Veatch reports that in South Australia where a royalty of 2.5 per cent. on net profits has been in effect in leases for half a century, the practical difficulty of ascertaining net profits is regarded as insurmountable. *Bulletin*, No. 505, *U. S. Geological Survey*, p. 62 (1912).

large profit to the two partners, the landlord and the operator. Such an element of possible graft as fattening the pay roll with inefficient and overpaid officials, perhaps related to the operator, could be prevented by conditions in the lease. Inasmuch as the operator's equitable share of the returns commonly would be by far the larger share, the inducement to this form of petty graft would not be so great in practice as would at first glance appear likely.

Thus far the landlord considered has been the private or corporate land owner. If the government is the landlord other factors enter into the problem, without, however, affecting the force or applicability of the principles already set down. Here the government, as the lessor, is acting in a dual capacity: namely, that of landlord and that of representative of the consumer. The larger public interest in the lease may thus relate to beneficial control of operation and production rather than to the revenue involved in the operation under the lease. The sharing between the owner and operator of the ultimate value of the resource developed has as its purpose the increasing of the ultimate return to the public, which may come in one of two ways, directly by increasing the royalty or indirectly by keeping down the price to the consumer. In certain cases, moreover, a low royalty rate, with low price, might stimulate consumption to so great an extent that it would yield an aggregate larger royalty than would result from a higher rate, thus giving a double benefit to the public.

The difficulties attending a valuation of government land for sale largely arise from the fact that the government has this double rôle. As the representative of the people the administrative officer hesitates to put so high a valuation upon the resource as to hinder its development or directly affect the cost and selling price of the product. Thus in the valuation of public coal lands, for instance, every element of uncertainty is resolved by the official representatives of the public in favor of the prospective buyer. Under leasehold these uncertainties as regards quantity of resource would disappear, for the royalty is paid only as the resource is developed. If the royalty be made to vary with net returns from the operation, so that the charge is determined as the result of actual division of profit, it will follow that the public, in its capacity as landlord, will get back a proportionate part of whatever it, in its capacity as consumer, pays for the product over and above the actual cost. In this sense the development of the natural resource will be put on a purely co-operative basis.

In the recently approved permit for the utilization of water power on Pend d'Oreille river or Clark fork of the Columbia, the use of

Federal lands is conditioned upon prompt construction and installation, with no charge during the period of development of works and of market. After 10 years the rate of compensation to the government varies inversely as the square of the proportional development of the site and directly as the square of the average price charged for electric energy to both customers and consumers. While protection of the ultimate consumer is the purpose of these terms, the return to the government, as will be seen, is determined by the receipts of the operator. Furthermore, since operating costs doubtless vary within a smaller range than selling prices, this royalty, which varies with the square of the average price, becomes one based more nearly upon net profits than upon gross receipts.

As applied to the development of any natural resource belonging to the people the practical effect of a leasehold plan wherein the royalty would be a certain proportion of net returns resulting from the development of each particular resource will be threefold: 1. A certain part of the element of risk will be eliminated, thereby making possible a lower factor of safety in the operation finances, so that the cost can be reduced, to the possible benefit of the consumer; at least there will be one less reason for excessively high prices to the consumer. 2. Any false excuse for exorbitant prices to the consumer will be prevented by open books. 3. An equitable sharing of profit between the owner and the developer of the resource will be possible because, with the relative equities between these two partners determined, that division of profits will be applied directly to actual returns rather than to estimates representing long-range predictions or only partial determinations.

The present-day tendency is to recognize more and more the public-service nature of great industrial developments. Governmental regulation is not only an accomplished fact in intraurban as well as interstate transportation but is rapidly becoming a realized ideal in the conduct of other corporate business the products of which constitute the necessities of life. Thus the combination of public ownership and private operation in the utilization of natural resources, such as the great supplies of mineral fuels and fertilizers or of timber or of water power remaining in public ownership, may be regarded as simply a logical phase of present-day progress. With the government as a partner, possessing a common interest in the profits of development, the individual or corporate operator should expect sympathetic co-operation and a minimum of administrative supervision, with its attendant evils of unnecessary overhead charges and costly delays. We might even attain that ideal of production which accomplishes the lowering of prices by keeping down costs.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

## The Substitution of Air for Water in Diamond Drilling.

BY RALPH WILCOX, MIAMI, ARIZ.

(Butte Meeting, August, 1913.)

THE diamond drilling of certain characters of unstable rock formation, as, for example, the copper-bearing schists of the Miami district in Arizona, is rendered most difficult by what is known as "caving" of the sides of the drill holes. As this caving is very greatly increased by the action of flowing water, it occurred to me, after experiencing a great deal of difficulty with caving in diamond-drill holes which I was drilling for the Miami Copper Co., that if I could substitute air for water, much of the caving—with resultant difficulties, such as decreased speed of sinking and increased consumption of diamonds—would be overcome.

After some experimenting, I found that it was perfectly practicable to substitute air for the water; forcing the air down the hollow rotating rods in the same manner as is done with water, the air passing out around the bit, which is thus cooled, and ascending on the outside of the rods to the collar of the hole, carrying the borings in just as satisfactory a manner as had been done by the water, but without the accompanying destruction or caving of the sides of the drill holes such as had been so generally experienced with the water. When water was encountered in the drilling this water was forced up to the collar just as it would have been had water been used in the drilling, but with the correspondingly decreased flow there was relatively less washing or caving of the sides of the drill holes.

The only change necessary in the arrangement of the drill is that a cross instead of a tee is used at the collar of the hole. A tightly woven jute bag is attached to one arm of the cross, for collecting and filtering the sample; and when drilling in dry ground a jet of water is attached to the opposite arm of the cross, to collect the dust and wash down the sample into the bag. The rods rotate through a stuffing box attached to the upper opening of the cross. The distention of the jute bag by the issuing air indicates the operating conditions as sufficiently as did the flow of water when using water in the drill hole.

The small percentage of core recovery rendered it necessary to

rely almost entirely upon sludge samples. Great care was taken in recovering these samples, which were all weighed to detect the presence of caving. A winze has lately been completed which was sunk on one of the drill holes for the purpose of checking the sludge samples; the samples from the winze and the samples obtained in the drill hole checked accurately.

The experience at Miami in the use of air has extended over six months and has shown that the refrigerating action of the air in expanding around the bit is effective in cooling the bit and the diamond consumption has not increased; it has not been found necessary to decrease the speed of rotation of the bit. The difficulties of operating in the friable copper-bearing schist have been decreased fully 75 per cent. by the use of air, and the sample weights and the results of sampling checked perfectly. There is no indication as to whether one would be limited as to depth in dry holes; our greatest required depth was about 300 ft.

Tests as to amount of air used showed a maximum consumption of 82 cu. ft. of free air per minute, while the least with which operating was practicable was 23 cu. ft. of free air per minute. The average used during the several tests was 47 cu. ft. of free air per minute, at 75 lb. pressure. A No. 1 Excelsior meter was used for these measurements, the meter being tested before and after making the measurements.

Apart from affording much relief in diamond drilling of friable rock such as above referred to,—probably the worst in which diamond drilling has ever been done,—there arises the possibility of drilling in regions where a scarcity of water would otherwise prevent operating. Drilling in these regions could be accomplished by the use of a portable compressor driven by a gasoline engine, which is another not inconsiderable advantage which the use of air instead of water in diamond drilling offers.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 west 39th Street, New York, N. Y.

## The Discovery and Opening of a New Phosphate Field in the United States.

BY CHARLES COLCOCK JONES, LOS ANGELES, CAL.

(Butte Meeting, August, 1913.)

In the winter of 1902, while occupying the position of mining and examining engineer for the Mountain Copper Co., Ltd., of Keswick, Cal., I had occasion to discuss with the General Manager, among other things, the question of the enormous waste of sulphur in smelting cupriferos pyrite ore, and to cast about for means to utilize this waste or to render the fumes innocuous to vegetation. The decreasing rate of production of California farms, the consequent need of fertilizers, and the opportunity thus offered to utilize large quantities of sulphuric acid in the manufacture of superphosphates naturally brought the subject to the practical and commercial side of phosphates.

I was informed that the company had made efforts to find phosphates in the West, without success. I advised as a start placing inquiries for phosphate deposits on the Pacific coast in the current mining journals. This was done, with the result that in January, 1903, from an advertisement in the *Mining and Scientific Press* we got track of a deposit in Rich county, Utah, through T. J. Wilson, of the Southern Pacific railroad in San Francisco.

As soon as snow in the mountains would permit, in May, 1903, I undertook an examination of the property, with the result of recognizing the importance of the find, in spite of its lack of facilities for transportation at a commercial figure.

On June 15, 1903, I concluded my report by saying, "This may be one of the world's deposits of phosphates." On Nov. 17, 1903, I concluded my report for the season in the following words: "I have now no hesitation in saying that I believe the Carboniferous formation so largely developed in the Wasatch mountains of Utah and the mountains of the Great Basin will prove to be one of the greatest storehouses of phosphoric acid in the world."

### *Early History.*

In the summer of 1897 R. A. Pidcock, a mail carrier of Ogden, Utah, while on a prospecting trip camped on "12 mile," a branch of

Woodruff creek, Rich county, Utah, in T. 8 N., R. 5 E., Salt Lake Meridian. Finding some old workings in a soft black formation and believing from returns on certain samples that he had a gold mine, he and others took up a number of claims in August and September, 1897. A mining excitement of the usual kind ensued and a large area of country was staked.

O. A. Kennedy, of Ogden, visited the camp Oct. 30, 1897, and later sent samples of the ore (phosphate rock) to the U. S. Geological Survey and to Prof. J. F. Kemp, of Columbia College, requesting analysis, but no returns were ever received.

The principal claims were incorporated into the Alice Mining Co., which during 1898 and 1899 did considerable development work without finding any more gold or silver. Finally a large sample was sent to Thomas Price & Sons, of San Francisco, for analysis and treatment. The returns showed no gold or silver, but revealed the fact that the material was phosphate rock, the following analysis being made by that firm:

|                              | Per Cent. |
|------------------------------|-----------|
| Phosphoric acid.....         | 32.44     |
| Iron and alumina oxides..... | 1.52      |
| Iron sulphide.....           | 1.72      |
| Calcium oxide.....           | 43.02     |
| Magnesium.....               | 0.83      |
| Carbon dioxide.....          | 0.85      |
| Sulphur trioxide.....        | 2.24      |
| Fluorine.....                | 1.36      |
| Organic matter.....          | 5.83      |

32.44 per cent. phosphoric acid corresponds to 70.18 per cent. tricalcic or bone phosphate.

One by one the stockholders dropped out until Frank Howe, a mail carrier of Ogden and one of the original locators, was the sole owner of the claims. His persistent belief in the value of the property was rewarded by the sale of it in 1903 to the agents of the Mountain Copper Co., Ltd., through T. J. Wilson, of San Francisco.

#### *Woodruff Creek Deposits, Rich County, Utah.*

In May, 1903, accompanied by Frank Howe, the owner, I examined the deposits of phosphate rock on Woodruff creek, 11 miles west of the town of Woodruff in the Bear River valley. Evanston, Wyo., on the Union Pacific, 24 miles south of Woodruff, is the nearest railroad station.

The phosphate formation extends for about 2.5 miles through Sections 16 and 9 and into Sections 21 and 4, T. 8 N., R. 5 E., Salt Lake Meridian, and dips from nearly vertical to 45° W. No geological



maps of this region were available except in the atlas of the *Geological Exploration of the Fortieth Parallel*, by Clarence King, and this portion was mapped as the Vermilion Creek formation, of Eocene age. The formation as exposed showed dipping to the west a great thickness of quartzite with underlying limestones, in which latter the phosphate occurred as a component bed.

The unconformity between the phosphate-bearing formation and the Vermilion Creek was apparent, and previous to the finding of distinctive fossils I was inclined to place the phosphate in the Silurian, from its general similarity to the deposits in the Bala limestones of Wales as figured by Dr. Penrose in *Bulletin* No. 65 of the U. S. Geological Survey.

An examination of a series of fossils from the apparently underlying limestones by Dr. G. H. Girty proved the formation to be Upper Carboniferous. On Aug. 28, 1903, the U. S. Geological Survey wrote me as follows:

DEPARTMENT OF THE INTERIOR,  
UNITED STATES GEOLOGICAL SURVEY,  
WASHINGTON, D. C.

August 28, 1903.

Mr. Charles Colcock Jones,  
Box 393, Ogden, Utah.

Sir:

Your letter with accompanying specimens has been referred to Dr. G. H. Girty of this survey, who submits the following report:

"The fossils sent in by Mr. Jones prove to belong in the late upper Carboniferous and not, as was supposed, in the Silurian. The following species are identified: *Stenopora* sp., *Productus* sp., *Spiriferina pulchra*, and *Seminula subtilita*. The horizon is that called upper Coal Measures in the section of the Wasatch Mountains established by the U. S. Geological Survey of the 40th parallel. It occurs above the Weber quartzite and below the Permian-carboniferous as defined by that organization."

As the fossils prove to be interesting and rather better preserved than usual, you would confer an obligation on us by furnishing the locality where they were found, and, if possible, by sending more material from the same beds, for which thanks are enclosed.

Very respectfully,

(Signed) H. C. RIZER,

Acting Director.

Here was a confusion in the very beginning. The error in mapping the Vermilion was understandable by reason of the immense territory sought to be covered in a short space of time by the Survey of the 40th Parallel and the comparatively small and isolated area involved, but the position of the fossils in a horizon above the Weber quartzite, but really lying in present position under it, was not clearly worked out until the following year. This will be gone into later in discussing the relations of several of the deposits.

The valley of Bear river follows the line between Utah and Wyoming, with the river flowing north, and has an elevation at Evanston, Wyo., of 6,755 ft. A. T. and at Woodruff, Utah, of 6,450 ft. A. T. It is an old Eocene basin, and going west from Woodruff up Woodruff creek the foothills are made up of Tertiary strata, lying flat or dipping very slightly, composed of soft red and white sandstones and conglomerates designated by the Survey as the Vermilion Creek formation.

On a general north and south line through Townships 7 and 8 N., R. 5 E., S. L. M., the Tertiary strata are found to lie uncomfortably on the Upper Carboniferous, which latter in the process of mountain building has experienced an overturning of the strata. Fig. 1 is a general section.

In addition to work done by Howe and associates in Section 16 an incline pit 20 ft. in depth had been sunk long previous on what was thought to be either an oil shale or coal blossom in Section 4.

From the imperfect openings available at the time the following is a general section of the phosphate formation, beginning at east side and going west:

Limestone, comparatively pure.

Cherty limestone and layers of black chert.

Principal bed of hard black oölitic phosphate, 4 ft., 66 to 78 per cent. bone phosphate.

30 ft. of intercalated black limestones and carbonaceous phosphatic shale, 19 to 45 per cent. bone phosphate.

300 ft. heavy bedded crystalline limestones.

Quartite.

The higher-grade phosphate occurs as brownish black oölitic stratified rock with a highly fetid odor, the oölitic structure being very regular and with only a minimum amount of interstitial matter. The rock weathers readily to individual grains, except a few layers of hard oölitic phosphate.

Further search failed to find the phosphate formation immediately north or south of the 2.5 miles spoken of on Woodruff creek and trips were taken in several directions.

A careful study of Hayden's Report of 1871 and the text of the 40th Parallel Survey by Clarence King caused me to examine the Ogden and Echo Cañon regions. The remarkable Z contortion in the Lower Carboniferous limestones spoken of by these writers consists of a series of black limestones and shales 16 ft. or more in thickness bearing from 2 to 24 per cent. lime phosphate, with a 1-in. black oölitic band carrying 48 per cent. lime phosphate.

A like occurrence of this same horizon will also be found in a cañon several miles south of Logan, Utah. There is nothing commercially

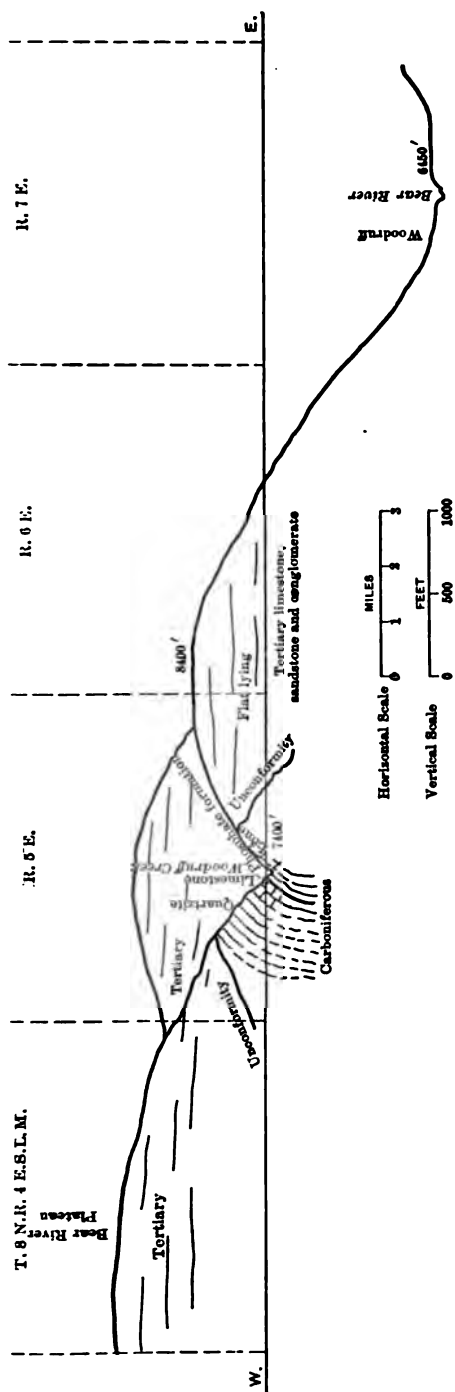


FIG. 1.—PHOSPHATE DEPOSITS AT WOODRUFF CREEK, UTAH.

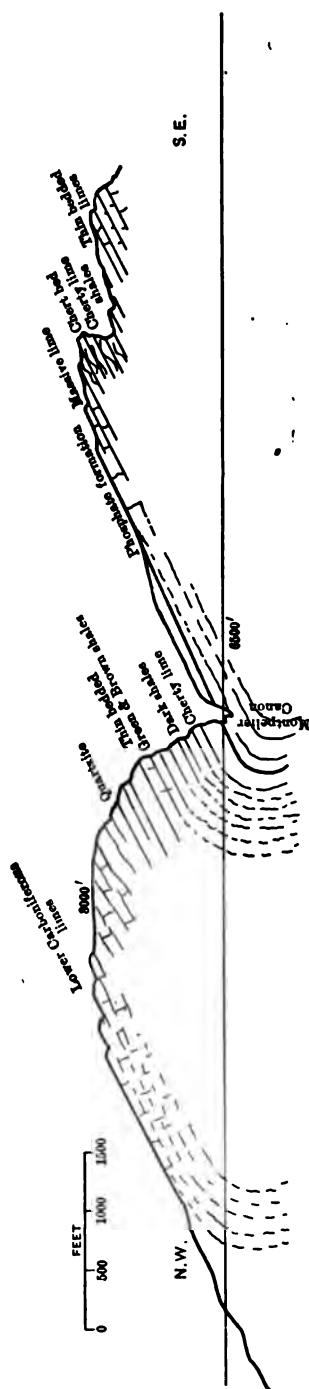


FIG. 2.—GENERAL SECTION AT MONTEPELIER CANON, IDAHO.

valuable about it, but it has great significance as being the earliest occurrence of oölitic bedded phosphate I have been able to find from the Cambrian to the Carboniferous, and may have had some influence, by the degradation of large areas, in forming the later deposits, or if not that, bearing to an extent on the subject of the origin of the deposits as governed by the bathymetric conditions prevailing at the time of the Upper and Lower Carboniferous limestones, separated by the great thickness of the Weber quartzite.

In August, 1903, I learned of work being done near the town of Montpelier, Bear Lake county, Idaho, for coal, and upon visiting the locality I found an incline shaft 250 ft. deep had been sunk by T. L. Glenn and associates in the geologically lower black shaly limestone strata of the phosphate formation. Summarizing the matter from a large amount of exploration covering this and the succeeding year, the following are the conditions and conclusions: The phosphate formation is exposed in Montpelier cañon 3 miles east of the town for a distance of 1 mile south in Sections 6 and 7, T. 13 S., R. 45 E., B. M., and 2 miles north in Sections 30 and 31, T. 12 S., R. 45 E., B. M.

The strata composing the entire mountain just north and south of the cañon occupy an inverted position, with the geologically upper rich bed of phosphate lying at the bottom, and the mountain at this point represents a part of an immense reverse fold. The strata strike in a general north and south direction, with a dip to the west of from  $20^{\circ}$  to  $40^{\circ}$ . A feature which has already confused geologists and engineers is the occurrence at Montpelier cañon of a thick bed of cherty limestone both above and below the phosphate formation, bearing the same set of fossils. In its normal position the most remarkable bed of chert and cherty limestone lies geologically above the phosphate and serves as a means of solving some of the problems encountered in searching for and placing the phosphate formation, entirely aside from the co-ordinating of like phosphate members of beds at widely separated points. This peculiarity is emphasized by the absence of any distinctive quartzite or indurated sandstone bed comparable to the Weber quartzite, the place of which seems to be taken by the cherty lime and shale beds at the mouth of the cañon, although a mile further north the quartzite is again in evidence 1,000 ft. thick.

The following replies to my letters to the Director of the U. S. Geological Survey are of interest and show the ready assistance afforded by the Survey in pursuing my investigations:

DEPARTMENT OF THE INTERIOR,  
UNITED STATES GEOLOGICAL SURVEY,  
WASHINGTON, D. C.

Nov. 6, 1903.

Mr. Charles Colcock Jones,  
Ogden, Utah.

Dear Sir :

Your letter of October 12 and accompanying specimens were referred to Mr. C. H. Girty of this Survey, who makes the following report :

"The fossils from near Montpelier, Idaho (lot 2), sent in by Mr. Jones are unquestionably Upper Carboniferous; and while it is perhaps hazardous in the present state of our knowledge to go beyond this statement, I believe that their horizon is quite well up toward the Permian. It is perhaps not very far from that of the fossils from Woodruff Creek, though the two faunas have little in common. The bodies shown in lot 3 are in my opinion not fossils, but concretions or segregations of some sort."

We thank you for the additional fossils from Woodruff Creek, and would be glad to obtain some more of the material from Montpelier, which is of considerable interest. In case you have any to spare, some franks are enclosed herewith.

Very respectfully,  
(Signed)CHAS. D. WALCOTT,  
*Director.*DEPARTMENT OF THE INTERIOR,  
UNITED STATES GEOLOGICAL SURVEY,  
WASHINGTON, D. C.

May 27th, 1904.

Mr. Charles Colcock Jones,  
Montpelier, Idaho.

Dear Sir :

Your letter of May 20th and accompanying fossils have been received, and referred to Mr. G. H. Girty, who submits the following report upon them :

"The fossils from Idaho sent by Mr. C. C. Jones unfortunately are new, or little known forms, so that it is possible in most cases only to point out the species to which they are allied, rather than to make a precise identification. The following types have been discriminated :

*Lot No. 1.*Chonetes, near C. Geinitzanus Waagen and C. permianus Shumard.  
Productus nevadensis Meek?  
Omphalotrochus? obtusispira Shumard?*Lot No. 2.*Chonetes, near C. Geinitzanus Waagen and C. permianus Shumard.  
Productus n. sp., near P. aagardi Toul.  
Pugnas n. sp. near P. kayseri Tschernyschew.  
Squamularia n. sp.  
Schizodus sp. indet.  
Omphalotrochus? obtusispira?  
Omphalotrochus? sp., near the foregoing.

"The two lots have essentially the same fauna, and the horizon is without much doubt high in the Upper Carboniferous—probably not Permian, though not far below it.

"The specimen of Lot No. 1 marked "A" is a *Productus* of the *punctatus* type. It is so imperfect that it can not be identified with certainty, but other better preserved exam-

ples from the same place indicate that its characters are more like Meek's species of the same group, *P. nevadensis*.

"The specimen resembling calcified wood, from Lot No. 2, is probably inorganic—a fibrous, or rather columnar, form of calcite. Calcified wood is rare, and this specimen has not the woody structure.

"Flints and cherts have in many cases been shown to be derived from the siliceous skeletons of sponges, partly in their organic shapes, and partly dissolved and redeposited. The first hypothesis therefore, would be that the cherts mentioned by Mr. Jones have a similar origin, even if no spicules can be detected. Cherts are, however, sometimes quite secondary in their origin, and result from comparatively recent replacements.

"It would be hazardous to venture any definite opinion about the bathymetric conditions prevailing at the time these fossils existed. It is probable that the conditions were not those of a shore deposit nor, on the other hand, of the deep sea. I should judge that the waters were rather shallow or of moderate depth.

"It is asked that you will convey to Mr. Jones an expression of thanks for this collection of fossils, which was sent in response to a request originating with me."

Very respectfully,

(Signed) H. C. RIZER,  
Acting Director.

DEPARTMENT OF THE INTERIOR,  
UNITED STATES GEOLOGICAL SURVEY,  
WASHINGTON, D. C.

August 23rd, 1904.

Mr. Charles Colcock Jones,  
5th East Hotel,  
Salt Lake City, Utah.

Sir:

The specimens accompanying your letter of August 5th were referred to Mr. G. H. Girty, who reports as follows:

"A fossil bearing rock in Lot 1 contains several specimens of *Chonetes*, probably relative to *C. Geinitzianus* and *C. Permianus*. They probably indicate the Permian or Permian-Carboniferous age of the rocks in which they occur. The few impressions of fossils in Lot 2 can not be determined. It seems probable that the phosphatic nodules and grains (oolitic) are segregations, contemporaneous with the material in which they are enclosed, and not a later enrichment of the rock."

Very respectfully,

(Signed) H. C. RIZER,  
Chief Clerk.

The fossils identified in letter of May 27 are all from the underlying and overlying cherty limestones and intercalated lime beds of the phosphate formation.

The fossil-bearing rock mentioned in Lot 1 of letter of Aug. 23, 1904, comes from the top of the series in the chert member.

At Montpelier cañon the phosphate formation occupies a position as a component series of strata in the general lime measures forming the Upper Carboniferous lying above the Weber quartzite. Fig. 2 is a general cross-section at this point, and Figs. 3, 4, and 5 are views showing the character of the formation.

At the bottom geologically it consists of a series of black phos-



FIG. 3.—FACE OF TUNNEL SOUTH OF MONTPELIER CREEK, SHOWING BLOCKY PHOSPHATE AT BOTTOM.



FIG. 4.—PHOSPHATIC LIMES AND SHALES, MOUTH OF MONTPELIER CAÑON, SHOWING LIME CONCRETION.



FIG. 5.—OUTCROP OF 6-FT. BED OF PHOSPHATE, MONTPELIER, IDAHO.

phatic mud beds, black or brown phosphatic shaly limes, lime concretions, and more or less pure beds of limestone, about 60 ft. in thickness, containing from 10 to 53 per cent. bone phosphate of lime, the amount of phosphoric acid in any one bed seeming to be subject to rapid changes in a short distance. A large part of this measure will undoubtedly be found capable of concentration when needed. Sharply divided from this lower member by a band 20 in. thick of hard black limestone, at places very full of *omphalotrochus* shell casts and other fossils, comes the top and commercially workable layer of phosphate rock, 5 ft. 6 in. in thickness. This bed is made up of two members, a lower (geologically) shaly member averaging 2 ft. in thickness, separated by a thin shaly mud seam, exactly similar to a slate parting in a coal bed, from the upper, harder, more blocky phosphate of an average thickness of 3 ft. The whole bed can be classed generally as a black oölitic phosphate very much of the appearance of the bedded black phosphate of Tennessee, and averages 70 per cent. bone phosphate. The fossils are from the intercalated limestones in the phosphate formation. In only one instance have I found a shell directly in the phosphate bed proper and that at Cokeville, Wyo.

From developments at the Hot Springs on Bear lake, 15 miles south, and Thomas fork, 15 miles east, and at Cokeville, 20 miles southeast of the Montpelier deposit, the workable bed described above has held its character and relative position with a definiteness similar to a coal bed over such an area, especially as regards the parting. In other parts of the field its changes are only of such a nature as would be expected in a coal bed of a like area. I draw the comparison at this point to emphasize certain ideas I shall advance later as to its mode of formation and origin.

The next determination of the bed was made by me in the summer of 1904 near Rich's Hot Springs in Section 13, T. 15 S., R. 44 E., B. M. Fig. 6 is a general cross-section at this point.

Again we find the strata in an inverted position, a point I will take up after the description of several further deposits. As will be seen from the detailed section, the workable bed is slightly different from that at Montpelier and the richest bed yet found in the field occurs as a separate one, 18 to 22 in. in width, composed of hard black oölitic phosphate with a layer of curious saucer or disk shaped concretions, all high-grade phosphate.

The formation has been traced through Sections 13, 12 and 1, T. 15 S., R. 45 E., and Sections 36 and 25, T. 14 S., R. 45 E., Boise Meridian, outcropping nearly north and south, with a dip to the west



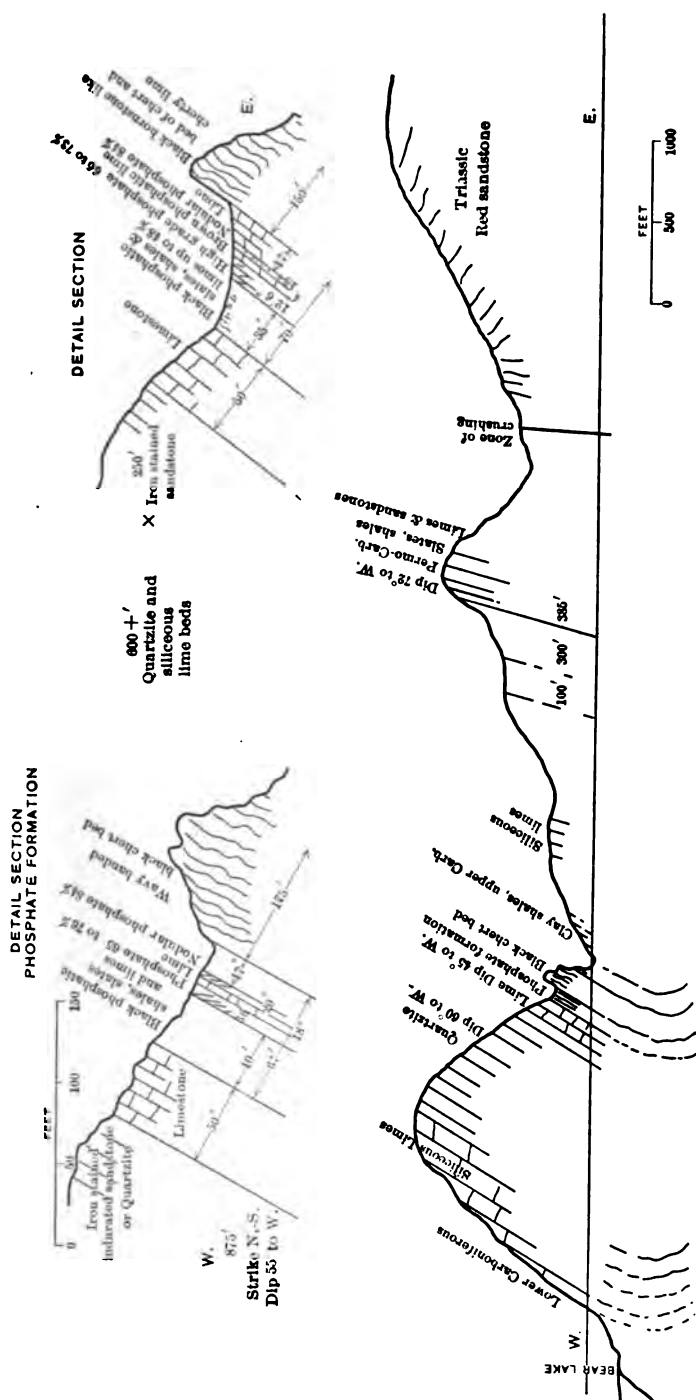


FIG. 6.—SECTION AT RICH'S HOT SPRINGS, IDAHO.

of 45° to 70°. The black chert bed forms a prominent feature, standing up like a dike for 3 miles, Fig. 7.

At the north end in Section 25 the following appears to be the section, beginning at the bottom, geologically, on the east side:

|                                                |             | Bone Phosphate.<br>Per Cent. |
|------------------------------------------------|-------------|------------------------------|
| Cherty lime bed.....                           | 100 + ft.   | .....                        |
| Lime.....                                      | 9 in.       | .....                        |
| Nodular phosphate.....                         | 2 in.       | .....                        |
| Lime.....                                      | 15 ft.      | .....                        |
| Concretionary oölitic phosphate.....           | 15 in.      | 78.00                        |
| Lime with thin bands of oölitic phosphate..... | 4 ft. 3 in. | .....                        |
| Gray oölitic phosphate..                       | 4 ft. 6 in. | 62.40                        |
| Gray oölitic phosphate.....                    | 3 ft. 6 in. | 72.80                        |
| Parting shale.....                             | 15 in.      | .....                        |
| Oölitic phosphate.....                         | 2 ft. 6 in. | 59.25                        |
| Black carbonaceous shales.....                 | 8 + ft.     | 50.75                        |

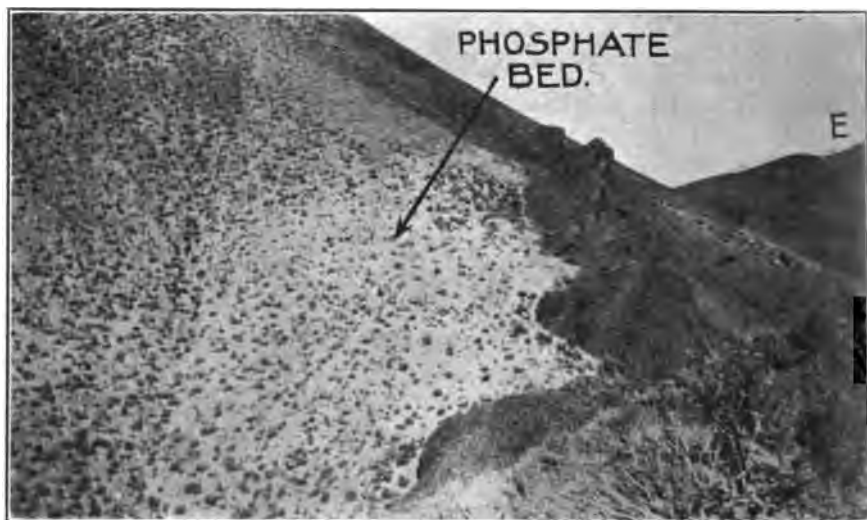


FIG. 7.—CHERT LEDGE AT RICH'S HOT SPRINGS, IDAHO.

This is the first exposure south of Montpelier cañon, and while differing somewhat from either the Montpelier section or the Hot Springs section, the relative position of the workable bed at the top of the series is the same.

In November, 1903, Frank Howe discovered the phosphate formation north of Croymen Station in Section 4, T. 4 N., R. 3 E., S. L. M. Upon examination I found that it corresponded in position with the Woodruff Creek and Montpelier deposits. The geology of this section is well defined by the Survey of the 40th Parallel. At the point

of discovery the formation strikes N. 70° E. and stands vertical or dipping to the northeast. The openings showed a considerable width of material running from 20 to 56 per cent. bone phosphate with intercalated lime ledges. In the spring of 1904 I discovered in Section 34, T. 4 N., R. 3 E., S.L.M., the south extension of the formation 1 mile south of the Union Pacific railway and followed it between the two points at the Weber river and on Dry creek.

The following is a section in N. E.  $\frac{1}{4}$  of Section 34, T. 4 N., R. 3 E., S.L.M., beginning at bottom and rising in the geological scale; strike N. 50° E.; dip 45° SE.:

|                                                                             |                  |                                           |
|-----------------------------------------------------------------------------|------------------|-------------------------------------------|
| Weber quartzite.....                                                        | 5,000 ft.; King. |                                           |
| Cherty lime.....                                                            | 220 ft.          |                                           |
| Phosphate opening.....                                                      | 7 ft. 4 in.      | { Average 45 per cent.<br>bone phosphate. |
| Covered with lime débris.....                                               | 40 ft.           |                                           |
| Yellow phosphatic limes.....                                                | 38 ft.           |                                           |
| Cherty limestones.....                                                      | 11 ft.           |                                           |
| Covered with lime débris.....                                               | 92 ft.           |                                           |
| Hard cherty lime.....                                                       | 61 ft.           |                                           |
| Thin-bedded shaly limes with thin bands of<br>hard siliceous phosphate..... | 23 ft.           |                                           |
| Hard black phosphate containing nodules.....                                | 2 ft. 3 in.      |                                           |
| Hard gray and black cherty limestone with cal-<br>cite nodules.....         | 32 ft.           |                                           |
| Heavy-bedded gray limestones.                                               |                  |                                           |

The phosphate formation in the cañon south of this is covered by the later formation unconformably and its next appearance is just east of Salt Lake City, north of Fort Douglas. It had been prospected here as elsewhere for coal. The strike is NW-SE. and the dip 45° to the northeast. It shows about 100 ft. of phosphatic limes, and cherty beds with a few thin oölitic bands, but apparently no workable bed of commercial value.

#### *Western Wyoming and Eastern Utah.*

In the summer of 1904 I was directed to some workings that had been prospected for coal a number of years previous in the north half of Section 7, T. 26 N., R. 119 W. of 6th P.M. in the Sublette range of mountains of Wyoming, just east of the Idaho line, on Thomas fork of Bear river. From this I determined the phosphate formation, running nearly north and south, dipping from vertical to 65° to the east through Sections 18, 7, and 6, T. 26 N., R. 119 W. 6th P.M. Fig. 8 is a typical section at the line between Sections 6 and 7, T. 26 N., R. 119 W. 6th P.M.; elevation 6,600 ft. A. T.

The east bed is the commercially workable one, and the similarity



to the Montpelier deposits is marked, even to the shale or mud partings separating the two members of the bed. The heavy black cherty bed lying above the phosphate formation is easily correlated with the same bed at Rich's Hot Springs and at Montpelier cañon, and the succession of strata from this in ascending order geologically is as perfect as at the latter place. The working out of the geology in this section and later south of it convinces me that the lowest bed at Montpelier in its present position was really geologically the top one. Analyses are shown on the cross-section.

In November, 1904, finding the Carboniferous to outcrop in two sharp peaks, 1 mile east of Cokeville, Wyo., in Section 4, T. 25 N., R. 119 W. 6th P. M., on patented land of John W. Stoner, I entered into negotiations with him to examine and acquire the lands in the spring when the snow was off. The result of the examination showed the quartzite, about 1,000 ft. thick, to form the ridge in the form of a close fold. The phosphate formation follows to the east and dips under the valley of Smith's fork of Bear river in a broad syncline, showing exposures of the rocks from the Carboniferous to the Cretaceous, with the phosphate formation again exposed, 8 miles east of Cokeville in Sublette cañon, dipping to the west.

Later investigations showed the continuation of the latter exposure to the south on Rock creek, but so far without commercial beds being opened.

Fig. 9 is a typical section at Cokeville, and the photographs, Figs. 10, 11, and 12, show the physical appearance of the bed.

In July, 1905, I discovered a small exposure of the Carboniferous in the low hills 1.5 miles east of Sage Station, Wyo., on the Oregon Short Line railway.

The occurrence here is on the west side of a gentle anticline, the west side of which has been abruptly faulted in the making of the Bear River valley. Compared with other exposures the phosphate formation is thin. At the base is the Weber quartzite, forming the backbone of the ridge; overlying this is a series of thin, bedded limestones about 125 ft. thick. Then comes the phosphate formation, not to exceed 30 ft. thick, covered by the characteristic cherty limestone, the whole dipping about 25° to west and striking north and south through Sections 2, 11 and 15, T. 21 N., R. 120 W. 6th P. M.

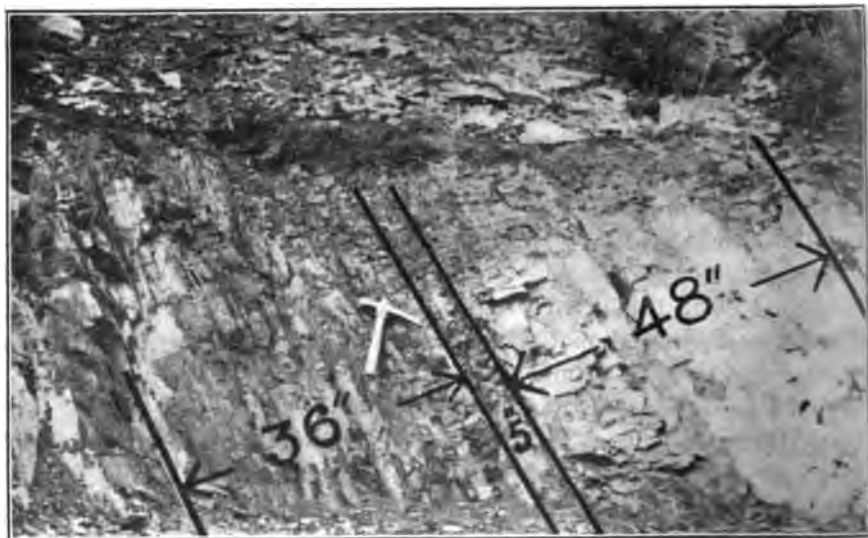
So far as developed there seems to be a workable bed from 7 to 10 ft. thick, showing a top member of 4 ft. of hard, jaspery red and green oily looking rock averaging 74 per cent. bone phosphate separated by a 5-in. shaly parting from 6 ft. of soft gray oölitic rock running as high as 80 per cent. bone phosphate.



FIG. 10.—PHOSPHATE WORKINGS NEAR  
COKEVILLE, WYO.



FIG. 11.—SURFACE WORKINGS AT  
COKEVILLE, WYO.



Lower Member.                      Parting.                      Upper Member.  
FIG. 12.—OUTCROP OF PHOSPHATE BED NEAR COKEVILLE, WYO.

The continuation of this formation was located by the Bradley interests in the Bear hills east of Bear river in Utah in Sections 5, 17, and 19, T. 11 N., R. 8 E., S. L. M., and by myself in Sections 18; and 19, T. 11 N., R. 8 E.

The Bear River fault has brought up the Carboniferous formation a very steep mountain in which the formation is exposed by faulting and erosion in both an anticline and a syncline showing the phosphate formation in several parallel lines.

A section at Brazier cañon in Section 18, T. 11 N., R. 8 E., S. L. M., is shown in Fig. 13.

At Bennington, Idaho, in the NE.  $\frac{1}{4}$  of Section 14, T. 12 S., R. 4 E., a disconnected and faulted portion of the phosphate formation is shown. A tunnel at this point, run as a coal prospect, has crosscut the formation 45 ft., striking N. and S. and dipping to the west. The material runs from 25 to 50 per cent. bone phosphate. Further work will be necessary to determine its position and relation to the other deposits.

In the west half of Section 21, T. 14 S., R. 43 E., B. M., 2 miles west of the town of Bloomington, Idaho, a phosphate formation about 75 ft. thick has been opened by a tunnel prospecting for coal. It consists of beds of very light weight brownish porous material devoid of oölitic structure or casts. In value it runs from 12 to 45 per cent. bone phosphate, with only a few feet of the latter. The correlation of this with the other deposits is also a matter for further investigation, although it appears to be in the Upper Carboniferous. The strike is N.  $30^{\circ}$  W., dip  $45^{\circ}$  to SW.

Thirty miles north of Montpelier I have found the phosphate formation in a cañon north of Soda Springs, Idaho, and at a number of points between the two places locations have since been made by various parties. A casual examination of these shows the general conditions as already described.

From a great number of analyses, the following are the general characteristics of the rocks:

Moisture rarely exceeds 1 per cent. and averages about 0.4 per cent., obviating any drying of the rock, which disintegrates readily by weathering without absorbing moisture to any appreciable extent. Insoluble runs from 5 to 7 per cent.; iron and alumina, below 3 per cent.

Regular shipments of lime phosphate from 63 to 75 per cent. and higher can be made by separating special beds up to several feet thickness. The specific gravity is from 2.85 to 2.98. There is considerable organic matter, which will be a slight detriment in making superphosphate.

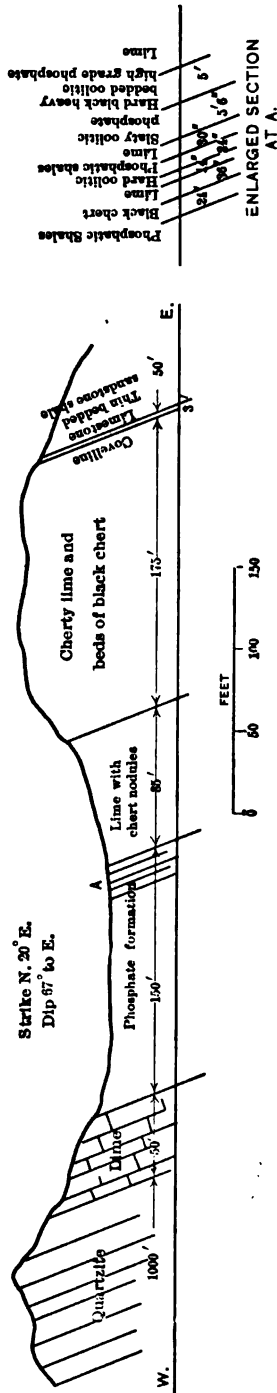


FIG. 13.—SECTION ON NORTH SIDE OF BRAZIER CANON.



Situated as the field is, practically half way between the Mississippi river and the Pacific coast, transportation will always be a serious item, especially as far as any export business is concerned, which is, perhaps, a good thing.

At present there are three concerns active in developing and shipping: The San Francisco Chemical Co., the operating department for the Mountain Copper Co., Ltd., which latter is an English concern, shipping to the coast from Montpelier, Idaho; the Union Phosphate Co., of San Francisco, which acquired my interests, shipping from Cokeville, Wyo., to the coast; the Bradley interests, shipping at Sage Station, Wyo., from Utah deposits.

The exposures in highly tilted beds render mining above water level a simple matter for a long time to come.

### *General Remarks.*

The work outlined above, primarily undertaken by me in the interests of the Mountain Copper Co., Ltd., up to June, 1904, and later conducted by myself personally, has demonstrated the existence of a very large phosphate field in the high intermountain country of northeastern Utah, southeastern Idaho, and western Wyoming. The occurrence is as bedded or stratified deposits in the Upper Carboniferous lying above the Weber quartzite of the 40th Parallel Survey, or an analogous formation. The principal rich deposits so far as found seem to lie in that arm of the Carboniferous sea bounded on the north and east by the granite backbone of the Rocky mountains in Wyoming, with a few islands of the same granite lying to the west. It must have been a shallow sea, devoid of currents, so far as we can judge from the bedding of the limestones, with the waters richly charged with phosphoric acid, which by animal, vegetable, and chemical means has concentrated into the beds of oölitic character.

The source of the enormous amount of phosphoric acid is an interesting one, and I hazard the suggestion that a study of the granitic areas surrounding this ancient sea may afford a clue to its origin. There also may have been injections of phosphoric material from volcanic sources, and while the Leucite hills of Wyoming, with their abnormal content of phosphoric acid, are long subsequent to the Carboniferous, they show at least a deep-seated source for phosphoric acid which may also have been active in a contiguous area during the Carboniferous age. The description of the Carboniferous sea by Dana is interesting as bearing on the subject.

The Carboniferous formation is exposed in the area under consideration in a series of north and south mountain ranges, as a result of

block faulting on a large scale, resulting in limited monoclines, anticlines, synclines, and close folds. The valley of Bear river is especially interesting as following a series of faults; rising about 60 miles east of the Great Salt lake, it follows north for a distance of 120 miles and then turns west and south to Great Salt lake.

Especially interesting and worthy of special study is the cherty bed overlying the phosphate formation at the top of the Carboniferous. In places it attains a thickness of 175 ft. of bands of black sinuously bedded hornstone-like material and at others is a mass of dumbbell disk, lily, or sponge-like and other fantastic forms in the lime. There is also a wide distribution of cherty forms in the underlying lime and quartzite beds. The conclusion is forced upon me that these represent sponge or beds of other low organisms.

In the phosphate formation we seem to have a gradually enriched series of beds from the bottom upward, the top bed being the most uniform and practically workable one.

An examination of the geologic folios of Carboniferous areas in the intermountain section shows a constant reference to chert and black or dark beds at the horizon in question, and I feel convinced that future search with the key afforded by the investigations already made will greatly enlarge the field. Much of the country is at present commercially inaccessible. A wise Providence seems to have made the Carboniferous coal bearing in the Appalachian and phosphate bearing in the Rocky Mountain region, the difference arising in the one being a swamp with a collection and laying up of vegetable material, and the other a shallow sea with the deposit by animal, vegetable, and chemical means of the vast amount of phosphoric acid borne by it from the degradation of the land areas.

It behooves the government of the United States to preserve for future generations this great storehouse of phosphoric acid, so essential to the wellbeing of any nation, and not to allow it to be distributed to every other nation for the temporary profit of a few dollars. This can be protected now when the private holdings are comparatively small and the bulk of it still to be discovered on the public domain. It would seem to be a legitimate function of the U. S. Geological Survey to have control of the matter.

LOS ANGELES, CAL., Jan. 23, 1907.

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The foregoing is the copy of a paper hurriedly prepared on the request made to me in one of the following letters, which are reproduced in chronologic order.

The appended letter to the President contains, I believe, the first suggestion as to the national conservation of our phosphate resources; and while the procedure has not yet worked out in the rational way I had in mind, it is in such shape that simple legislation ought to open the way for leasing on some such basis as coal. In the meantime there seems ample competition in the field to supply the present markets properly.

MONTPELIER, IDAHO, October 16, 1906.

To His Excellency,  
Theodore Roosevelt,  
President of the United States,  
Washington, D. C.

Sir:

I have the honor to address you on a subject worthy of your close investigation.

In removing from entry all remaining coal lands in the public domain I would suggest that there be included also all phosphate lands.

In 1903 I undertook to search for phosphate lands in the West in the interest of the Mountain Copper Company of California. In that search I was successful in finding what promises to be the largest phosphate field in the world, lying in Western Wyoming, Idaho, Utah and Nevada.

Certain irreconcilable differences arising between myself as an American Engineer and the above alien English corporation caused a severance of our relations in 1904. Since that time, on my own means and initiative I have made further vast discoveries which in 1905 became the property of a domestic California corporation.

In making to you the suggestion to remove from location and entry all phosphate lands remaining on the public domain until the subject can be thoroughly investigated by the U. S. Geological Survey I am actuated by motives of the purest patriotism. By remaining quiet I could probably make a great deal of money in the next few years, but looking ahead I can see that the field will probably be owned and dominated by vast interests inimical to the best interest of the nation as a whole.

Phosphates and phosphoric acid are necessary to the human race in raising its food supplies and such deposits should essentially be the property of the nation, to be leased out under a proper system and in proper quantities to responsible parties.

The U. S. Geological Survey has recently had an engineer in the field and is aware of some of the facts I have given you above.

Now seems the time for action to preserve properly these deposits and I trust you will appreciate that I am writing you strictly from patriotic motives.

I am, sir,

Your obedient servant,

CHARLES COLCOCK JONES.

In answer to which I received the following:

DEPARTMENT OF THE INTERIOR,  
UNITED STATES GEOLOGICAL SURVEY,  
WASHINGTON, D. C.

Nov. 1, 1906.

Mr. Charles Colcock Jones,  
247 Pacific Electric Building,  
Los Angeles, California.

Sir:

Your letter of October 16 addressed to the President has been referred to this office for reply. I agree with you as to the desirability of preventing the newly discovered phos-

phate deposits of Idaho and adjacent States from falling into the hands of a monopoly. This result could doubtless be prevented by the withdrawal of the lands containing the deposits from mineral entry. Such withdrawal, however, involves a radical departure from the Government's policy with reference to mineral deposits on the public domain. A precedent for such withdrawal has, however, been established by the recent action of the President in regard to coal lands, and it is probable that he would look with favor on a similar line of action in connection with these phosphate deposits. It is necessary, however, before the withdrawal can be made that the exact location of the deposits should be known. Arrangements were made last winter with a geologist in private practice, who had been engaged in the examination of these phosphate deposits for some time, to prepare a report for Survey publication. Up to the present, however, this report has not materialized and the Survey, therefore, has no exact information regarding their location, on which to base recommendations. If such information is anywhere available I should be glad to receive it, and in any case have planned to make a thorough investigation of the deposits as early as possible next spring. I should be glad to receive from you any information you have regarding the location, character and value of the deposits. Such information will be treated as confidential and used only in such manner as may be approved by yourself.

Very respectfully,

H. C. RIZER,  
*Acting Director.*

LOS ANGELES, CAL., Dec. 5, 1906.

Director U. S. Geological Survey,  
Washington, D. C.

Dear Sir:

Your letter of November 1st, was received on my return to Los Angeles some few days ago; a continued absence in Utah and Idaho rendering it impossible to forward the same to me.

Since broaching this subject of the withdrawal of phosphate lands, I have given the matter considerable thought and during the time, have been over a large part of the field. As a practical question, I hardly see now how the withdrawal from entry could be accomplished, unless the Survey instituted a regular series of exploration which would prove up the available territory.

I find that it will be very much larger in extent than I had at first supposed.

A reference to my letters to the U. S. Geological Survey, beginning in August 1903, shows that the formation has been definitely determined as the upper carboniferous and this extends over vast areas of western Wyoming, Utah and Idaho, and while the present developments have proved the existence of phosphate in a number of places contiguous to railroads the exposures by reason of block faulting are comparatively few, so that the statement of the exact location of the deposits would be of little value as bearing on the question of withdrawal from entry.

Having been the original locator of most of these deposits and having, perhaps, the largest accumulation of information in my note books and reports on the subject, I feel that I am, perhaps, well qualified to make a report for publication on the subject.

I was disappointed, while recently in Salt Lake City, in not meeting Mr. Walcott as I would have been pleased to discuss the matter personally with him.

I am now working on my notes, maps, etc., with the intention of either submitting them during the next month to Lehigh University or to the Survey. The paper will deal with the entire history of the discovery and contain a great many facts, known only to myself, and I will be pleased to have the views of the Director in this matter.

I have had a number of slides made and would be pleased to learn from you where I can have micro-photographs of the same made.

Investigations, since forwarding my letter to the President have convinced me that the field is considerably larger than even I had thought it and while as a general proposi-

tion the conservation of such deposits for the people as a whole is desired, unless as I said, the Survey is prepared to have a special bureau investigate and establish the workable areas of phosphate lands to be withdrawn from entry it would be a drawback to development; however, it might be possible to so restrict holdings of lands as to obtain the object in view.

Very respectfully,

CHARLES COLCOCK JONES.

DEPARTMENT OF THE INTERIOR,  
UNITED STATES GEOLOGICAL SURVEY,  
WASHINGTON, D. C.

December 12, 1906.

Mr. Charles Colcock Jones,  
247 Pacific Electric Building,  
Los Angeles, California.

Dear Sir:

Referring to your letter of December 5, relating to phosphate lands in Utah and Idaho:

As stated in my letter of November 1, it is hoped that detailed examinations of these deposits may be undertaken next season. In view, however, of the great interest in this matter I should be glad to see published at an early date such information regarding them as is available. As you are doubtless aware, a volume is published each spring entitled *Contributions to Economic Geology*, made up largely of abstracts of more extended reports and short papers of economic interest. I am sending you under separate cover the bulletin for 1905. If you should care to prepare a brief paper for the 1906 bulletin and could submit it before February 1, 1907, I would be glad to consider its publication.

Very truly yours,

H. C. RIZER,  
Acting Director.

Acting upon this request the foregoing paper was written and forwarded with the following reply to letter of December 12:

LOS ANGELES, CALIFORNIA,  
January 23rd, 1907.

Director U. S. Geological Survey,  
Washington, D. C.

Dear Sir:

I have the honor to submit to you the brief paper for 1906 bulletin of *Contributions to Economic Geology*, as requested in your letter, of December 12th, 1906.

I enclose also with this, a drawing of the sections mentioned, from which tracings can be made at your office, and the combined map of those portions of Utah, Idaho and Wyoming with the known outcrops of the phosphate formation marked by red lines.

I have thought it best to put the preliminary article in its present form, not so much for any honor, as far as I am personally concerned, but as an interesting narrative of a work that absorbed me greatly as being somewhat of a guide to others in the field, carrying out investigations on a purely geological basis.

I have tried to make it so it would require as little editing as possible and leave it to your judgment as to the propriety of some of the last general sentiments expressed in the paper.

I am forwarding you also, illustrative photographs of openings and a box of microscopic slides, the latter of which, if not of any present use, can be returned to me.

In addition to the fossils, I have had the pleasure of forwarding you, I have a number

of interesting specimens which either now or later I will put at your disposal for illustrative purposes.

Trusting that this paper meets your wishes and hoping that I may be able to render you further service at any time, I am

Very truly yours,

CHARLES COLCOCK JONES.

Rather to my surprise this paper was returned with the following explanation :

In reply please refer to GB and date of this letter.

SUBJECT: Returning manuscript on phosphates of the United States.

DEPARTMENT OF THE INTERIOR,  
UNITED STATES GEOLOGICAL SURVEY,  
WASHINGTON, D. C.

February 2, 1907.

Mr. Charles Colcock Jones,  
247 Pacific Electric Building,  
Los Angeles, California.

Dear Sir :

Your letter of January 23, accompanied with a paper on the "Discovery and Opening of a new Phosphate Field in the United States," was duly received.

The paper has been carefully examined and in its present form is not adapted for publication in the *Contributions to Economic Geology*. Since this report will go to press in a few days there will be no opportunity for you to revise the paper. Moreover, as stated in my letter of November 1, 1906, arrangements were made last winter for the publication of a paper on this subject just received from the author, and this will be supplemented with information obtained by one of the Survey geologists during the past season. Your paper contains much matter of interest and I trust you will have it published so that this information may become available. I have no doubt that any of the mining journals would be very glad to secure it.

I am returning the manuscript and illustrations to you under separate cover, registered.

Very respectfully,

H. C. RIZER,  
*Acting Director.*

In the *Engineering and Mining Journal* of May 18, 1907, appeared an abstract from this paper, and which was perhaps the first actual description of the phosphate field.

Shortly afterwards *Contributions to Economic Geology*, 1906, was issued containing "Phosphate Deposits in the Western United States," by Weeks and Ferrier, and subsequent annual issues of the same publication have kept the world informed of the enormous extent of this phosphate field as its boundaries have been extended by the investigations of the Survey.

The remarkable thing about this phosphate field is that it lay unnoticed so long and practically undiscovered, for at Rich's Hot Springs on Bear lake characteristic phosphate openings were shown to many by the late Joseph Rich.

T. L. Gleen, of Montpelier, Idaho, while a member of Congress about 1904, submitted samples to the Smithsonian Institution, which reported the phosphatic material not a coal and worthless.

Since the opening of the field the statement has been made through the technical press by several that they knew of the existence of phosphate rock in Wyoming, but so far as I have been able to learn the analysis by Thomas Price & Son, in 1899, was the first authentic recognition of the true nature and value of the rock.

The Survey has accomplished a vast deal of work in the phosphate field, the results of which it has published with a wealth of detail in various publications. The following extracts from *Classification of the Public Lands*, 1913,<sup>1</sup> are illuminative:

#### *"Lands Containing Phosphate.*

"Deposits of phosphate in the Rocky Mountain States were first discovered in north-eastern Utah and southeastern Idaho, in the vicinity of the Idaho-Utah-Wyoming line. From this locality the deposits have been traced south, east, and west halfway across the States of Idaho, Utah, and Wyoming and northward to the vicinity of Helena, in west-central Montana, so that the phosphate beds now known cover an area extending about 220 miles from east to west and 420 miles from north to south. Of course only a small part of this territory is underlain by deposits that are commercially valuable."

"The estimated quantity of high-grade rock (containing 70 per cent. or more of tricalcium phosphate) included in the area surveyed in detail to date is more than 3,000,000,000 long tons."

#### *"Summary of Phosphate Situation.*

"The question of the future adequacy of our phosphate resources for our own needs had been mentioned by several authorities prior to the conference of the governors in 1908, in which the discussion of this and kindred topics drew public attention to the situation. At this conference the possibility that foreign investors might acquire the better-known and supposedly richer portions of our deposits was suggested, the wisdom of permitting the exportation of so essential a quasi-public commodity was questioned, and the desirability of an early examination of the available supplies was emphasized. In part as a result of these indications of public interest, in part as a continuation of the policy already adopted in reference to coal lands, and in part because of the legal dilemma existing in the western fields through the inadequacy of the laws governing the disposal of mineral land the Secretary of the Interior, on December 10, 1908, withdrew from entry about 7,000 square miles of public land in Idaho, Utah, and Wyoming, pending an examination of their phosphate resources. In the following summer the United States Geological Survey began the examination of these lands and the investigation has been continued up to the present time, some 4,000 square miles having been examined in a preliminary way and about 2,500 square miles surveyed in detail.

"The first withdrawal was based partly on information collected by the Hayden Survey in 1877 and partly on later detailed and reconnaissance examination made by the United States Geological Survey. Field work done subsequent to this withdrawal revealed the regularity and the character of the phosphate deposits, so that it has been possible not only to revise the estimates of the reserves in the area actually examined since the first withdrawal but also to make a closer interpretation of the information gathered by the earlier surveys."

<sup>1</sup> *Bulletin No. 537, U. S. Geological Survey*, pp. 124 to 127 (1913).





DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y.

## The Influence of Copper Upon the Physical Properties of Steel.

BY G. HOWELL CLEVINGER,\* PALO ALTO, CAL., AND BHUPENDRANATH RAY,  
CALCUTTA, INDIA.

(Butte Meeting, August, 1913).

FORMERLY great divergence of opinion existed in regard to the influence of copper in steel, as affecting its various physical properties. More recently the investigations of Stead,<sup>1</sup> Breuil,<sup>2</sup> Wigham,<sup>3</sup> Burgess and Aston,<sup>4</sup> Ball and Wingham,<sup>5</sup> Müller,<sup>6</sup> Dillner,<sup>7</sup> and others have shown fairly good agreement in the major points. Copper steel has been shown by these investigators to possess special properties which make it valuable for certain uses.

The general range of composition of the useful alloys of copper and iron, and of copper, iron, and carbon, has been quite definitely established, for the former by Burgess and Aston,<sup>8</sup> and for the latter by Breuil<sup>9</sup> and Stead.<sup>10</sup>

Stead<sup>11</sup> has removed one difficulty in reconciling certain of the earlier data by calling particular attention to the influence of carbon in copper steels. Another point which caused confusion in the earlier investigations, particularly in regard to "red-shortness," was the presence of sulphur. Failure to note the presence of sulphur often led to attributing "red-shortness" to the presence of small amounts of copper. Turner<sup>12</sup> has called attention to the fact that where copper exists in an iron ore it often occurs as the sulphide, so that the presence of copper in steel made from such ores might also, necessarily, mean the presence of sulphur. It is evident that the effect in this case might be quite different than where pure copper was added.

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\* Associate Professor of Metallurgy, Stanford University.

<sup>1</sup> *Journal of the Iron and Steel Institute*, vol. lx. (1901, II), p. 104.

<sup>2</sup> *Idem*, vol. lxxiv. (1907, II), p. 1.

<sup>3</sup> *Idem*, vol. lxxix. (1906, I), p. 222.

<sup>4</sup> *Transactions of the American Electrochemical Society*, vol. xvi., p. 241 (1909).

<sup>5</sup> *Journal of the Iron and Steel Institute*, vol. xxxiv. (1889, I), p. 123.

<sup>6</sup> Wedding: *Stahl und Eisen*, vol. xxvi., No. 23, p. 1444 (Dec. 1, 1906).

<sup>7</sup> *Idem*, vol. xxvi., No. 24, p. 1493 (Dec. 15, 1906).

<sup>8</sup> *Transactions of the American Electrochemical Society*, vol. xvi., p. 241 (1909).

<sup>9</sup> *Journal of the Iron and Steel Institute*, vol. lxxiv. (1907, II), p. 1.

<sup>10</sup> *Idem*, vol. lx. (1901, II), p. 104.

<sup>11</sup> *Idem*, p. 114.

<sup>12</sup> *Idem*, p. 138.

Unsound ingots, which are sometimes complained of with copper steel, may be due to the method of adding the copper. The well-known property which copper possesses of absorbing gases when molten, which are given off during solidification, and which makes the production of sound castings of pure copper difficult, has led us to think that the presence of copper might confer upon molten steel somewhat the same property. Our experience in making the crucible steel for this investigation points strongly to this conclusion; but it also indicates that this difficulty can be overcome by taking proper precautions in adding the copper.

In the past a most peculiar condition has existed as regards copper steel, in that while very little of it has been made intentionally, thousands of tons of both pig iron and steel have been placed upon the market, which contained copper, on account of copper occurring in the iron ores from which the pig iron or steel was made. All of this steel has apparently proved satisfactory in every way.

Frequently, where specimens of ordinary steel have shown unusual strength and hardness, and resistance to corrosion, in excess of what could be expected from ordinary carbon steels, it has been found upon analysis that the steel contained copper, present as an accidental constituent, but nevertheless effective in producing a superior grade of steel. This has often been the case where rails have shown unusual wear. In this connection copper steel would appear to approximate nickel steel, while, due to the smaller amount of copper necessary and its lower price, copper steel could be made at a less cost.

The purpose of this investigation has been to assist in removing the unfounded prejudices which have existed in the past in regard to copper steel.

#### EXPERIMENTAL.

*Making of Ingots.*—A small circular furnace, lined with silica brick and fired by means of a low-pressure burner, using California crude oil as a fuel, and not employing the regenerative principle, was used for heating the No. 25 graphite crucibles in which the steel was melted.

The raw materials used for making the steel consisted of mild steel punchings containing 0.23 per cent. of carbon, the best grade of electrolytic copper, 80 per cent. ferro-manganese, and a good grade of commercial aluminum.

The general method of procedure was to charge 30 lb. of punchings into the crucible and fire until the metal was melted. It generally required about 2 hours before the charge began to melt and

about one-half hour more for the metal to become perfectly fluid. The molten metal was then "killed" for from 20 to 25 min., after which 2.5 oz. of ferro-manganese was added and the metal thoroughly stirred. After from 5 to 7 min. more the required amount of copper was added and the metal again stirred. About 5 min. later 0.096 oz. of aluminum was added and then, after again stirring, the metal was at once poured into a previously heated ingot mold. Sufficient slag was added to each charge to form a protective coating over the molten metal. This was done with the idea of preventing, to a large extent, the absorption of gases by the metal after it had become fluid.

At first we encountered considerable difficulty in making sound ingots; but, after experience had taught us to proceed in the manner outlined above, every heat produced sound ingots free from blow-holes. While we did not have the opportunity of thoroughly investigating this phase of the subject, the two points which appear to us to be the most important in making copper steel by the crucible process are: 1. To thoroughly kill the metal before adding the copper. 2. To add some deoxidizing agent, as aluminum, just before pouring.

Each ingot weighed approximately 30 lb. and measured 3 by 8 by 12 in., with the exception of A0, which weighed 22.5 lb. and was 3 by 3 by 9 in.

After having determined the proper method of melting, eight ingots were made. In the making of this series of ingots all the conditions were maintained as nearly the same as possible, with the exception of the proportions of copper added as noted below.

| Designating Mark. | Per Cent of Copper Added. |
|-------------------|---------------------------|
| A0.....           | 0.00                      |
| A0.25.....        | 0.25                      |
| A0.5.....         | 0.50                      |
| A1.....           | 1.00                      |
| A2.....           | 2.00                      |
| A3.....           | 3.00                      |
| A4.....           | 4.00                      |
| A5.....           | 5.00                      |

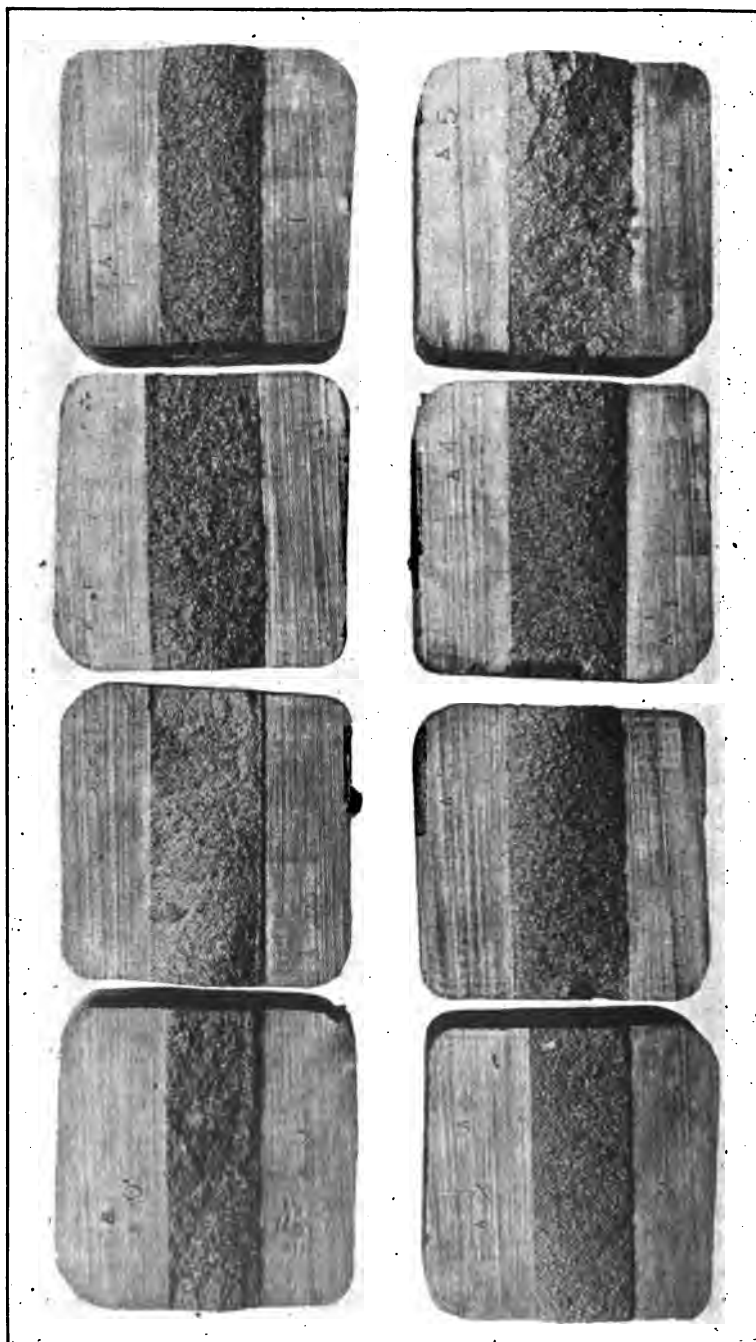
All of these ingots were sound and free from blow-holes. Each ingot was sawed to a depth of 1 in. on two opposite sides, 2 in. above the bottom. After breaking, a fracture area of approximately 1 by 3 in. was shown. The appearance of these fractures is shown in Fig. 1. In sawing and breaking the ingots the following facts were observed: A0 appeared to be rather soft and tough—about what would be expected of ordinary machine steel. The brittleness and fineness of grain became more evident with increasing copper content, except in the case of A5, which had a coarser grain than any of the other specimens.

A1

A0.5

A0.25

A0



A5

A4  
FIG. 1. FRACTURES OF INGOTS.

A2

Segregation was not noticeable to the eye in any of the ingots; all were white, lustrous, and uniformly grained in the fracture. There were reddish streaks of copper oxide, in the form of very thin films, on the surface of ingots A4 and A5.

The slags resulting from the steels containing the higher percentages of copper were slightly tinged red, presumably by the presence of copper oxide.

*Forging of Ingots.*—The eight ingots were heated in a large forge and reduced to 1½-in. octagonal bars by means of a steam hammer. All forged about like ordinary machine steel. A2 appeared to be somewhat softer than the rest. A5 shows traces of red-shortness and, after cooling, the surface of the bar showed minute cracks.

*Welding.*—Lap welds were tried upon the eight bars, with the following results:

A0—Seemed to weld perfectly at a bright red heat, almost yellow, similar to “machine steel.”

A0.25—Appeared rather overheated but welded easily.

A0.5—Could not be welded with the hand hammer at yellow heat, and welded with difficulty under the drop hammer at bright yellow.

A1—Welded moderately well under the drop hammer at bright yellow.

A2—At bright yellow, scintillating, welded with difficulty under the drop hammer.

A3—Could not be welded at any heat from red to almost white.

A4—The ends slipped off and crumbled to pieces at bright yellow under the drop hammer. Metallic copper showed on the surface of the heated ends when cold.

A5—The ends did not stick at any heat, resisted all attempts to weld; copper showed on the surface of the heated ends as in A4.

The failure to weld the steels containing the higher proportions of copper may have been due to the formation of a film of copper oxide upon the surface of the weld.

Test pieces were turned from the welded specimens and the ultimate breaking strength of these determined, with the results given below:

| Bar.       | Ultimate Breaking Strength<br>of Welded Test Pieces.<br>Pounds per Square Inch. | Ultimate Breaking<br>Strength of Unannealed<br>Test Pieces.<br>Pounds per Square Inch. |
|------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| A0.....    | 22,300                                                                          | 86,700                                                                                 |
| A0.25..... | 25,500                                                                          | 99,500                                                                                 |
| A0.5.....  | 88,200                                                                          | 99,000                                                                                 |
| A1.....    | 83,000                                                                          | 97,400                                                                                 |
| A2.....    | 39,600                                                                          | 120,660                                                                                |

A0 broke along the weld.

A0.25 broke along the weld.

A0.5 broke along and across the weld.

A1 broke along and across the weld.

A2 broke along the weld.



A0

A0.25

A0.5

A1

A2

FIG. 2.—WELDED SPECIMENS AFTER FRACTURE.

Fig. 2 is a photographic view of the welded specimens after fracture.

Different authorities do not agree as to the limit of copper content beyond which the steel is not capable of being welded.

The most remarkable welds of copper steels were those made by Colby<sup>13</sup> upon steels containing in most cases about 0.565 per cent. of copper. All his specimens were said to be capable of being successfully welded, and only one of them broke at the weld and this under a load of 61,630 lb. per square inch.

Definite conclusions in regard to the welding of copper steel cannot be drawn from the small number of results which we are able to present; but our results, together with those of Colby, would seem to indicate that it might be possible that steel containing from 0.5 to 1.0 per cent. of copper, while more difficult to weld, when once welded seems to produce a stronger union than a similar steel containing no copper.

*Chemical Analyses.*—The drillings for the chemical analyses were taken from the sides of the ingots, as indicated by the shaded areas in Fig. 3.

Copper was determined by ether separation followed by the iodate volumetric method. Carbon was determined by the total-combustion method, sulphur by the evolution method, phosphorus by Handy's volumetric method, manganese by Ford's method, and silicon by the regulation gravimetric method.

TABLE I.—*Analyses of Steel.*

|                                   | A0.       | A0.25.    | A0.5.     | A1.       | A2.       | A3.       | A4.       | A5.       |
|-----------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                                   | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Carbon .....                      | 0.46      | 0.606     | 0.523     | 0.471     | 0.533     | 0.437     | 0.442     | 0.462     |
| Manganese .....                   | 0.445     | 0.477     | 0.320     | 0.329     | 0.305     | 0.433     | 0.386     | 0.436     |
| Sulphur .....                     | 0.0385    | 0.0295    | 0.039     | 0.036     | 0.022     | 0.0206    | 0.021     | 0.0196    |
| Silicon .....                     | 0.076     | 0.078     | 0.094     | 0.060     | 0.052     | 0.066     | 0.060     | 0.066     |
| Phosphorus .....                  | 0.0172    | 0.0160    | 0.0189    | 0.0172    | 0.0210    | 0.0172    | 0.0203    | 0.0147    |
| Copper (B) .....                  |           | 0.165     | 0.493     | 0.846     | 1.857     | 2.773     | 3.574     | 4.512     |
| Copper .....                      |           |           |           | 0.888     |           | 2.609     |           | 4.371     |
| Copper, top of ingot (A) .....    |           |           |           | 0.849     |           | 2.796     |           | 5.640     |
| Copper, bottom of ingot (C) ..... |           |           |           |           |           |           |           |           |
| Copper added .....                |           | 0.25      | 0.50      | 1.00      | 2.00      | 3.00      | 4.00      | 5.00      |

*Effect of Copper in Eliminating Sulphur.*—Inspection of Table I. shows a regular decrease of sulphur with increasing copper content. Breuil's<sup>14</sup> analyses of his semi-mild steels (Table II.) show the same phenomenon, although certain of his other analyses seem to be contradictory. The results of certain other investigators seem to show the same tendency, but we are unable to quote them on account of not

<sup>13</sup> *Iron Age*, vol. lxi., No. 22, p. 1 (Nov. 30, 1899); also *Journal of the Iron and Steel Institute*, vol. lvii. (1900, I), p. 412.

<sup>14</sup> *Journal of the Iron and Steel Institute*, vol. lxxiv. (1907, II), p. 4.

knowing the exact conditions under which their steel was made, and on account of the further uncertainty of the effect of other factors, which might have had an influence upon the sulphur. However, it seems probable that copper does have an important effect upon the elimination of the sulphur. This point is worthy of further investigation.

TABLE II.—*Analyses of Semi-Mild Steel—Series B (Breuil).*

|                     | B0.       | B0.5.     | B1.       | B2.       | B4.       | B8.       | B16.      | B32.      |         |
|---------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|---------|
|                     | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |         |
| Carbon.....         | 0.386     | 0.390     | 0.400     | 0.389     | 0.368     | 0.372     | 0.412     | 0.282     |         |
| Manganese.....      | 0.150     | 0.139     | 0.164     | 0.175     | 0.139     | 0.135     | 0.160     | 0.230     |         |
| Silicon.....        | 0.316     | 0.323     | 0.307     | 0.242     | 0.217     | 0.316     | 0.298     | 0.214     |         |
| Phosphorus.....     | 0.020     | 0.020     | 0.022     | 0.023     | 0.022     | .....     | .....     | .....     |         |
| Sulphur.....        | 0.017     | 0.018     | 0.012     | 0.010     | 0.011     | .....     | .....     | .....     |         |
| Copper, bottom..... | 0.0       | 0.505     | 1.005     | 2.025     | 4.009     | 7.960     | 16.015    | Outside.  | Center. |
| Copper, top.....    | .....     | .....     | .....     | .....     | 3.985     | 7.910     | 15.985    | 24.4      | 74.8    |
|                     |           |           |           |           |           |           |           | 21.2      | 34.2    |

*Segregation of Copper in Ingots.*—Within the limits investigated, there was no segregation of the copper which was noticeable to the eye or which was apparent in the specimens examined under the microscope. This seems very strange in view of the fact that copper became evident upon the surface of A4 and A5 when an attempt was made to weld them. Determination of the copper in the samples taken at A, B, and C, Fig. 3, shows a slight tendency toward segregation in A1. In A3 this is more marked and in A5 it becomes serious. The tendency for copper to segregate toward the bottom of the ingot is marked.

Breuil<sup>15</sup> also noted higher percentages of copper in the bottom of his ingots than in the top, as will be seen from Table II. He failed to discover any difference in copper content between the bottoms and tops of ingots containing less than 4.0 per cent. of copper. He also found that very high copper steels formed an exterior shell with a lower percentage of copper and an interior core very rich in copper. He tested the homogeneity of the ingots by a method based upon the principle of Brinell's method of testing hardness, and found that ingots containing less than 30 per cent. of copper possess fairly uniform hardness from the skin toward the center. "Generally speaking, the hardness is greater at the bottoms of the ingots than the tops." "Ingots of steel containing less than 8 per cent. of copper show no coloration at their fractures. Between 8 per cent. and 20 per cent. of copper they are fairly uniform physically, and do not display marked segregation. Above 30 per cent. of copper the segregation is marked."

<sup>15</sup> *Journal of the Iron and Steel Institute*, vol. lxxiv. (1907 II), p. 6.



Stead<sup>16</sup> says it was found that "steel with 1 per cent. carbon would dissolve and retain in solution about 7 per cent. copper, and that when this amount is exceeded the excess is thrown out of the solution at the setting point and appears as globules." "When the proportion of copper is increased above 10 per cent., the suspended globules also increase, and when 25 per cent. copper is melted with 75 per cent. steel, a portion of the copper separates from the steel before it solidifies, and is found at the bottom of the ingot in a separate layer. It is, however, not pure, but is associated with about 10 per cent. iron, part of which is in solution and part as dendritic crystallites." Stead made an alloy of equal parts of copper and iron by melting them together in a charcoal-lined crucible and allowing the alloy to cool in the crucible. "It separated into two conjugate layers of the following composition:

|              | Top Layer.<br>Per Cent. | Bottom Layer.<br>Per Cent. |
|--------------|-------------------------|----------------------------|
| Iron.....    | 87.00                   | 9.60                       |
| Copper.....  | 10.34                   | 90.02                      |
| Carbon.....  | 2.07                    | 0.08                       |
| Silicon..... | 0.45                    | Nil                        |
| Etc.....     | 0.14                    | 0.30                       |
|              | 100.00                  | 100.00 "                   |

*Corrosion Tests.*—Cylindrical test pieces were turned from each forged bar, 0.5 in. in diameter and 0.5 in. long. These were thoroughly cleaned and weighed, and then completely immersed in glass beakers containing 400 cc. of 1:3 sulphuric acid which was maintained at 22° C. In order that sediment which formed might settle to the bottom of the beaker, and thus keep a fresh surface constantly exposed to the action of the acid, the small steel cylinders were supported upon tripods made of thin glass rod. The beaker was covered with a watch glass to prevent evaporation. Fig. 4 shows the general arrangement. The cylinders were left in the acid for 160 hours, after which they were taken out, washed, and thoroughly cleaned of all sediment, dried, and accurately weighed. The following table gives the percentage of loss suffered in each case at the end of 160 hours:

| Steel.     | Copper Content.<br>Per Cent. | Loss by Corrosion<br>in Acid.<br>Per Cent. |
|------------|------------------------------|--------------------------------------------|
| A0.....    | 0.0                          | 22.20                                      |
| A0.25..... | 0.165                        | 7.14                                       |
| A0.5.....  | 0.493                        | 5.35                                       |
| A1.....    | 0.846                        | 6.93                                       |
| A2.....    | 1.857                        | 11.31                                      |
| A3.....    | 2.773                        | 32.60                                      |
| A4.....    | 3.574                        | 37.00                                      |
| A5.....    | 4.512                        | 42.60                                      |

<sup>16</sup> *Journal of the Iron and Steel Institute*, vol. 1x. (1901, II), p. 114.

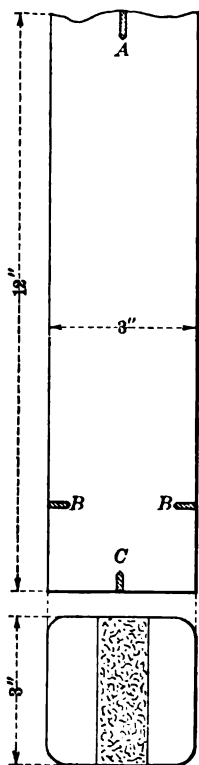


FIG. 3.—SHOWING POINTS DRILLED FOR ANALYSES.

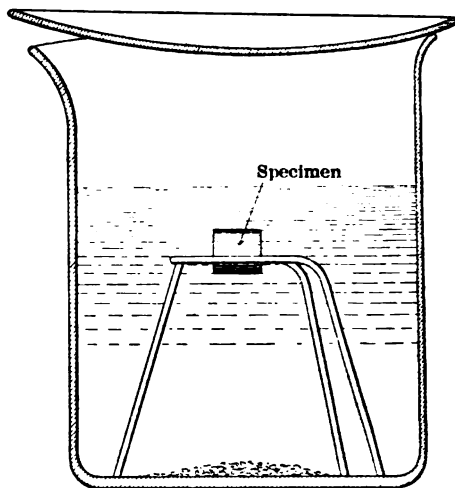


FIG. 4.—SPECIMEN SUPPORTED ON GLASS RODS FOR CORROSION TESTS.

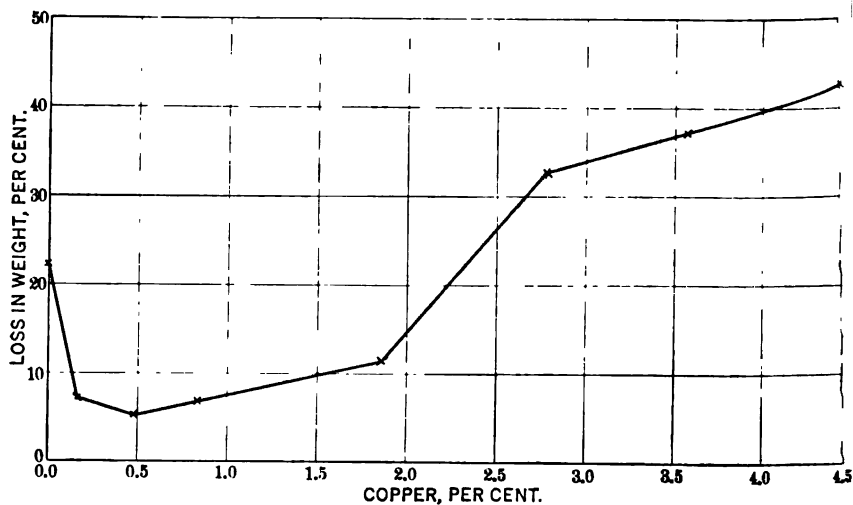


FIG. 5.—CURVE SHOWING CORROSION BY 1 : 3 SULPHURIC ACID.

Reference to the accompanying table and Fig. 5 will show that when no copper is present the loss in weight is 22.2 per cent.; 0.165 per cent. of copper lowers the loss to 7.14 per cent. The minimum loss, 5.35 per cent., occurs when 0.493 per cent. of copper is present. With 0.846 per cent. of copper the loss in weight is slightly increased, to 6.93 per cent.; 1.857 per cent. of copper raises the loss in weight to 11.31 per cent. Increasing the copper content to 2.773 per cent. causes an abrupt rise in the loss of weight to 32.6 per cent. From this point up to 4.512 per cent. of copper the rise in the loss of weight is regular and much less abrupt.

Sample A0 corroded very irregularly and was pitted and rifflled over the whole surface. All the copper steels corroded uniformly and evenly, leaving an almost smooth surface; the edges remained sharp and remarkably well preserved.

Breuil's<sup>17</sup> samples containing 0.5 per cent. of copper, in both the series containing 0.15 and 0.35 per cent. of carbon respectively, gave the minimum loss due to solvent action of the acid. This agrees with the results given above.

Walker<sup>18</sup> says, "In investigating samples of iron and steel which had withstood corrosion for years, and which notwithstanding dissolved in acid very readily, together with samples which withstood solution in acid in a remarkable manner, and yet were rusting at the ordinary rate, it was found that the acid resistant specimens contained in every case a substantial amount of copper; that is, the presence of copper seemed to be the controlling factor in the resistance to solution in acid."

He made tests upon basic open-hearth steels and obtained the following results:

|         | Carbon.<br>Per Cent. | Manganese.<br>Per Cent. | Sulphur.<br>Per Cent. | Phosphorus.<br>Per Cent. | Copper.<br>Per Cent. | Loss in Weight After<br>3 Hours in 20 Per<br>Cent. Sulphuric Acid.<br>Grams. |
|---------|----------------------|-------------------------|-----------------------|--------------------------|----------------------|------------------------------------------------------------------------------|
| A.....  | 0.08                 | 0.50                    | 0.018                 | 0.017                    | .....                | 0.2235                                                                       |
| A3..... | 0.08                 | 0.50                    | 0.018                 | 0.017                    | 0.21                 | 0.0075                                                                       |
| B.....  | 0.1                  | 0.41                    | 0.027                 | 0.026                    | 0.19                 | 0.0082                                                                       |
| C.....  | 0.09                 | 0.31                    | 0.031                 | 0.063                    | 0.19                 | 0.0095                                                                       |

The effect upon acid corrosion of small quantities of copper is strikingly shown by these results. He further observes that iron and steel in contact with metallic copper will dissolve more readily than when they form perfect mixtures, and he brings out the analogy of the case of zinc and copper, which are very actively attacked by acids if the two metals remain in contact with each other, but which

<sup>17</sup> *Journal of the Iron and Steel Institute*, vol. lxxiv. (1907, II), p. 61.

<sup>18</sup> *Metallurgical and Chemical Engineering*, vol. ix., No. 9, p. 453 (Sept., 1911).

are very little affected by the solvent action of the acid when melted into bars of brass.

The effect of atmospheric corrosion was studied by Williams.<sup>19</sup> Samples of Bessemer steel and wrought iron were frequently dipped in water and allowed to dry in the air. This operation was carried on for one month. As the percentage of copper increased the loss decreased. He gives the following table:

*Loss from Atmospheric Corrosion.*

|                                                     | Loss.<br>Per Cent. |
|-----------------------------------------------------|--------------------|
| A. Soft Bessemer steel.....                         | 1.85               |
| B. Soft Bessemer steel with 0.078 per cent. Cu..... | 0.89               |
| C. Soft Bessemer steel with 0.145 per cent. Cu..... | 0.75               |
| D. Soft Bessemer steel with 0.263 per cent. Cu..... | 0.74               |

*Steel and Wrought Iron.*

|                                                              |      |
|--------------------------------------------------------------|------|
| Soft Bessemer steel.....                                     | 1.65 |
| Wrought iron, Sample 1.....                                  | 0.76 |
| Wrought iron, Sample 2.....                                  | 0.80 |
| Wrought iron, Sample 3.....                                  | 0.87 |
| Wrought iron, Sample 4 (containing 0.393 per cent. Cu.)..... | 0.53 |

His results with copper steels are comparable with those of Howe<sup>20</sup> upon nickel steel.

Buck<sup>21</sup> has made an elaborate and convincing investigation of the effect of atmospheric corrosion upon steels containing small percentages of copper. In order that the conditions, except the copper content, should be the same in all cases, copper was added to portions of three heats, while the other portions were poured directly into ingot molds. The steel was made by the basic open-hearth, basic open-hearth (rephosphorized), and Bessemer processes. The steel to which copper was added actually contained 0.15, 0.24, and 0.34 per cent. of copper respectively. The steel was rolled into the regulation 16 and 27 gauge corrugated sheets. In addition there were purchased in the open market 16 and 27 gauge sheets which contained from 0.06 to 0.07 per cent. of copper.

Several sheets of each grade were placed in roofs at testing stations located in the Pennsylvania coke regions, where the air contains sulphuric and sulphurous acids and unprotected roofs corrode very rapidly; at the sea shore, where the air contains salt; and in a rural district where the air was free from corrosive agencies.

"In every case the steels with copper additions have shown a

<sup>19</sup> *Iron Age*, vol. lxi., No. 22, p. 16 (Nov. 29, 1900); also *Engineering and Mining Journal*, vol. lxx., No. 23, p. 667 (Dec. 8, 1900).

<sup>20</sup> *Metallurgy of Steel*, p. 371 (1890).

<sup>21</sup> *Journal of Industrial and Engineering Chemistry*, vol. v., No. 6, p. 447 (June, 1913).

marked resistance to corrosion as compared with the non-copper steels, having on the average nearly twice the life. There appears to be very little difference between the grades containing 0.15 copper and those with 0.24 to 0.34, while the material with low carbon and manganese and with 0.06 to 0.07 copper takes an intermediate position between the copper-bearing steels and those without copper."

Accelerated acid tests were made on 2 by 4 in. test pieces, cut from the same sheets as were used for the atmospheric corrosion tests, with 25 per cent. sulphuric acid at 35° C. "The copper-bearing Open-Hearth and Bessemer steels resist the acid from 50 to 100 times as well as the non-copper steels, and within the limits of the copper content of the steels used in this test, the resistance to the acid is directly proportional to the amount of copper present. In this regard the acid tests differ from the actual weather tests."

Burgess and Aston<sup>22</sup> have investigated the corrodibility of a number of alloys of electrolytic iron with other metals, in the making of which every precaution was taken to exclude other impurities. In their series of alloys of electrolytic iron with copper, the copper content ranged from 0.089 to 7.05 per cent. All of these show a high resistance to attack by acid, and also a low atmospheric corrosion for the whole series, and it is of particular interest to note the beneficial results from even small additions of copper. "The quality, both mechanically and from the corrosion point of view, is entirely comparable with that resulting from the use of corresponding amounts of nickel and, of course, there is a materially lessened cost for the addition."

*Microstructure.*—Two series of specimens were prepared for microscopic examination, one with the steel as forged, and the other annealed. The annealing was done at a temperature of 820° C. and at the same time that the bars were annealed for the annealed tensile test pieces. The etching agent employed was a 10 per cent. solution of concentrated nitric acid in absolute alcohol. In the case of some of the higher-copper alloys a subsequent application of a saturated solution of iodine in absolute alcohol was necessary. The specimens were polished and etched and the photographs were taken by H. M. Boylston in the laboratory of Sauveur & Boylston, Cambridge, Mass.

Upon examination of the micrographs, Figs. 6 to 21, it will be seen that in the case of the unannealed specimens the ferrite is permeated with filaments of cementite more or less in proportion as the percentage of copper increases. Larger patches of free ferrite appear in the specimens with decreasing copper content and the pearlite is less

<sup>22</sup> *Journal of Industrial and Engineering Chemistry*, vol. v., No. 6, p. 458 (June, 1913).

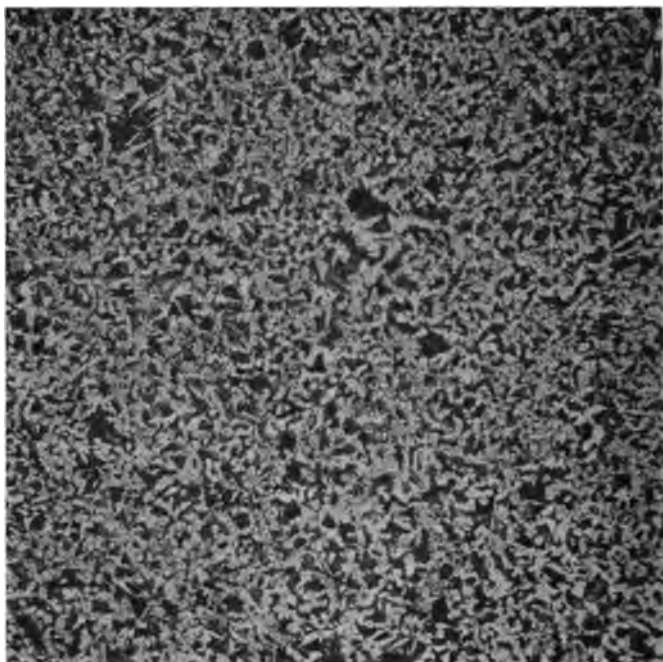


FIG. 6.—SPECIMEN A0.  $\times 100$ .

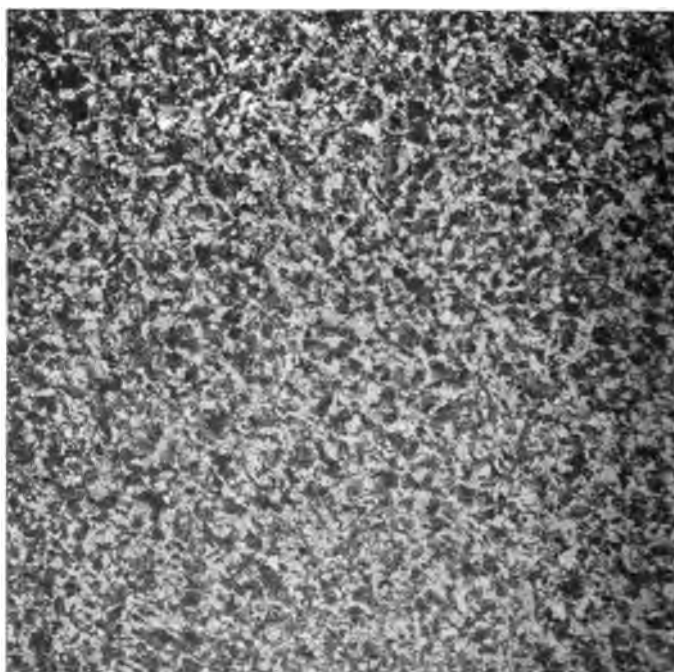


FIG. 7.—SPECIMEN A0A.  $\times 100$ .

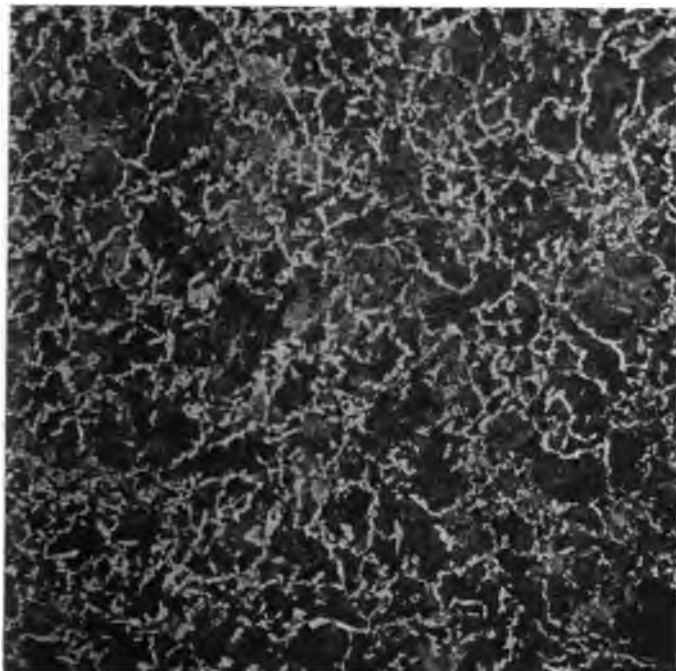


FIG. 8.—SPECIMEN A0.25.

× 100.

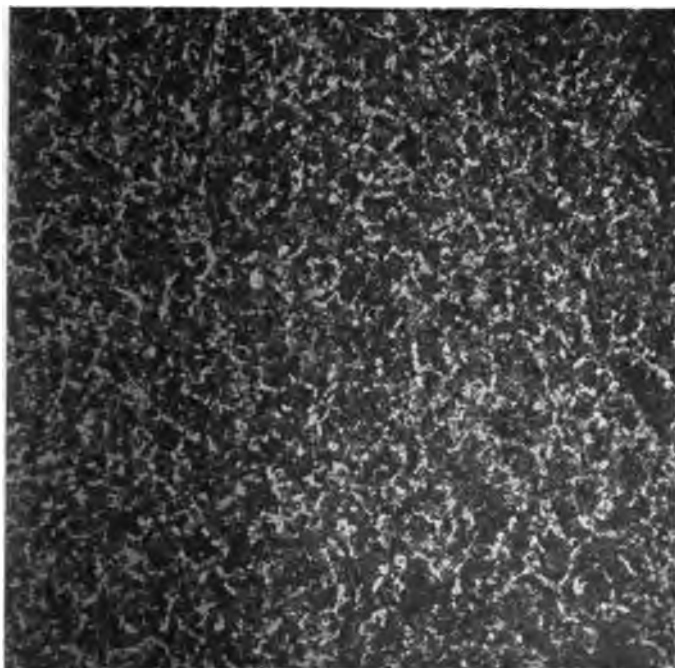


FIG. 9.—SPECIMEN A0.25A.

× 100.

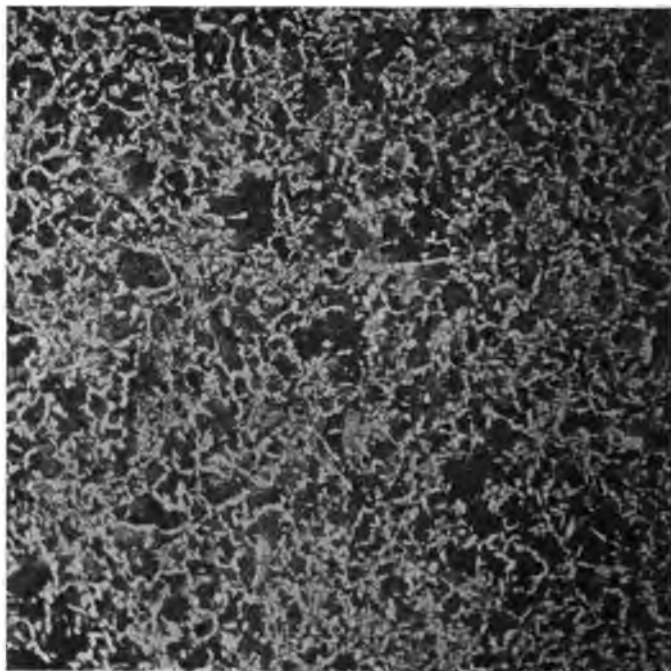


FIG. 10.—SPECIMEN A0.5.  $\times 100$ .

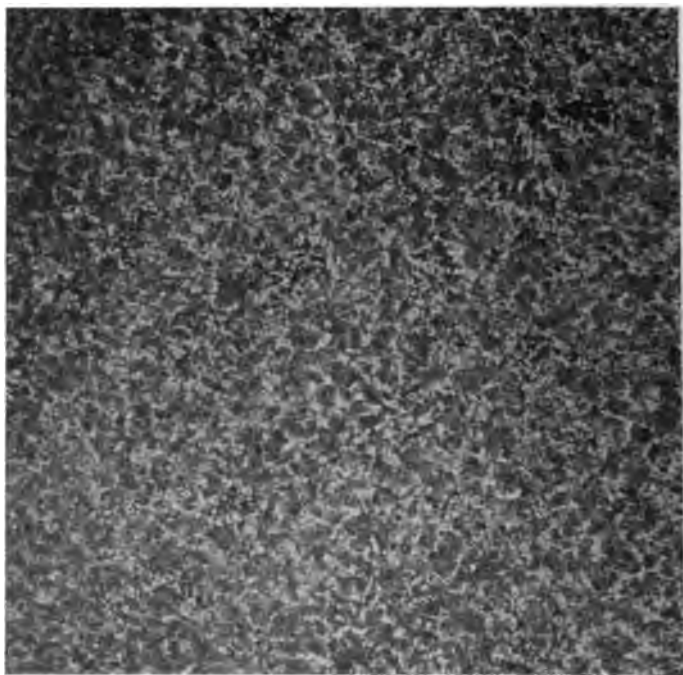


FIG. 11.—SPECIMEN A0.5A.  $\times 100$ .



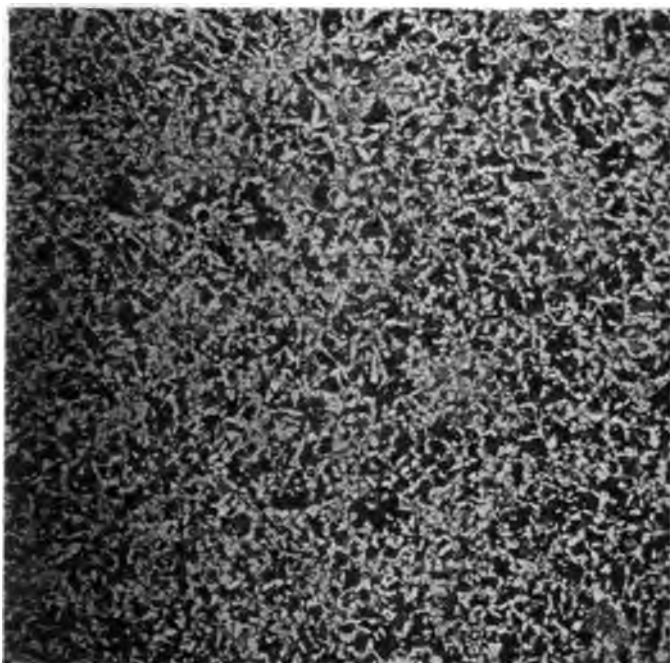


FIG. 12 —SPECIMEN A1.  $\times 100$ .

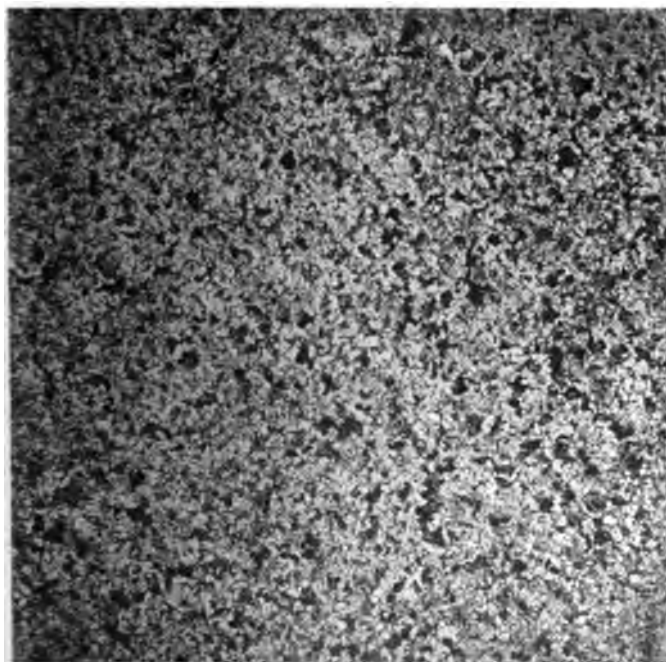


FIG. 13.—SPECIMEN A1A.  $\times 100$ .

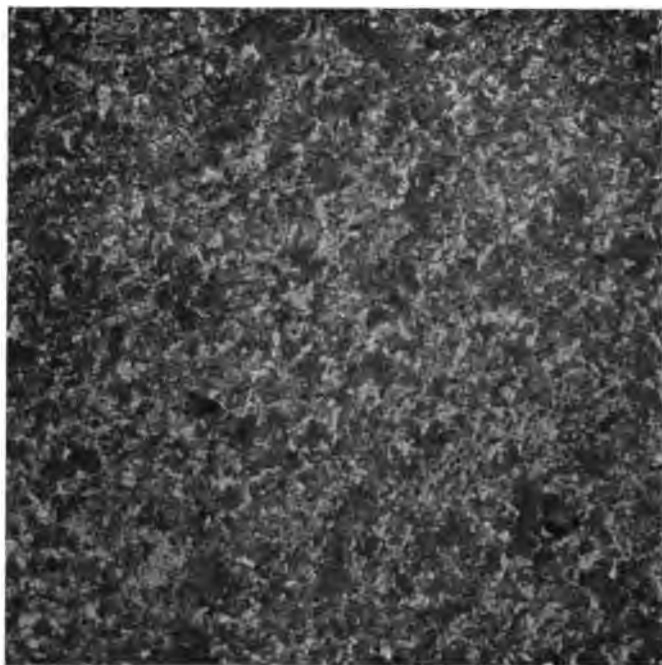


FIG. 14.—SPECIMEN A2.

× 100.

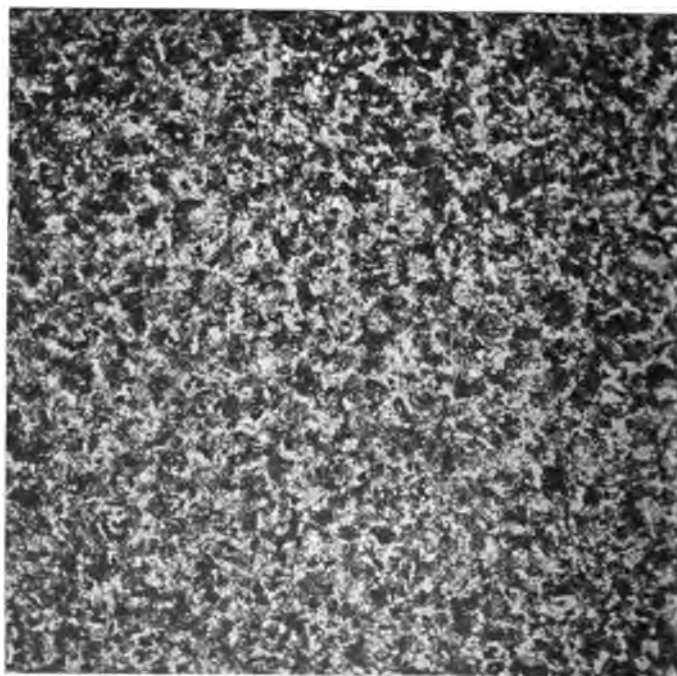


FIG. 15.—SPECIMEN A2A.

× 100.

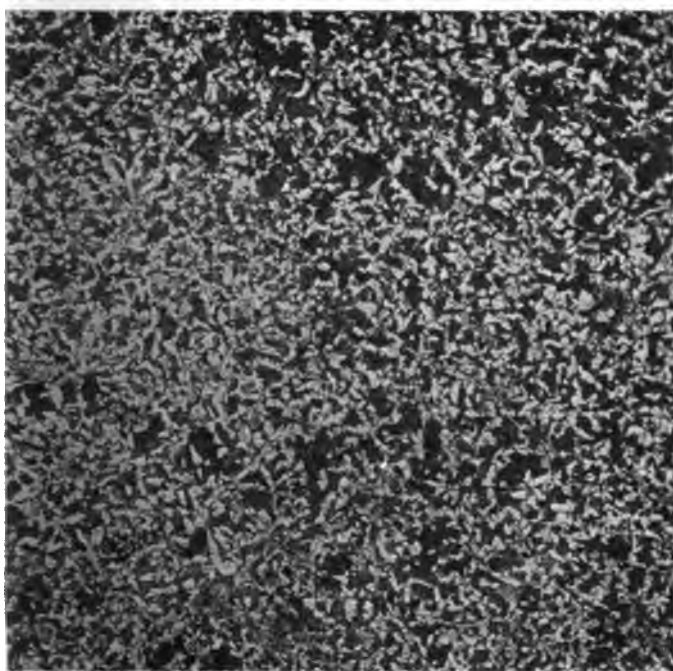


FIG. 16.—SPECIMEN A3.  $\times 100$ .

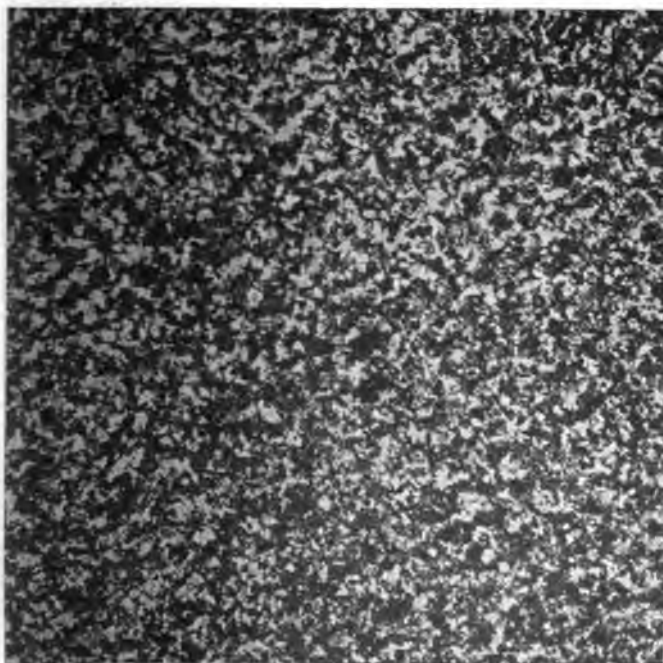


FIG. 17.—SPECIMEN A3A.  $\times 100$ .

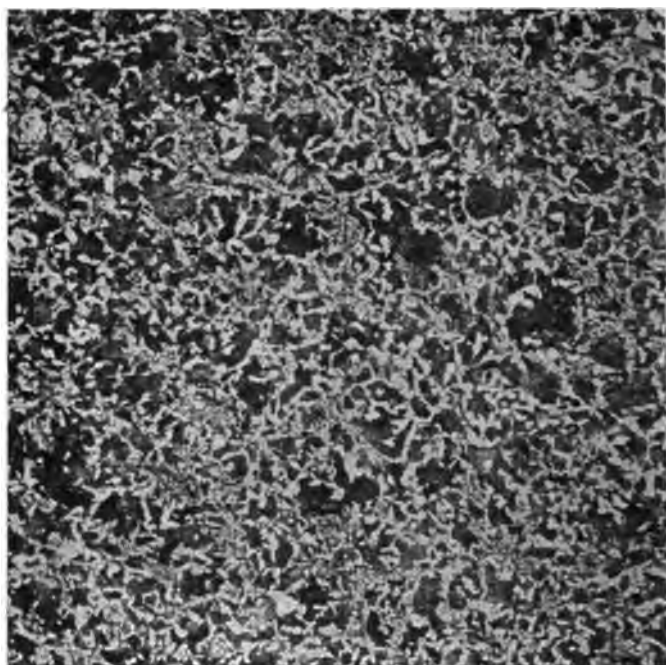


FIG. 18.—SPECIMEN A4.

× 100.

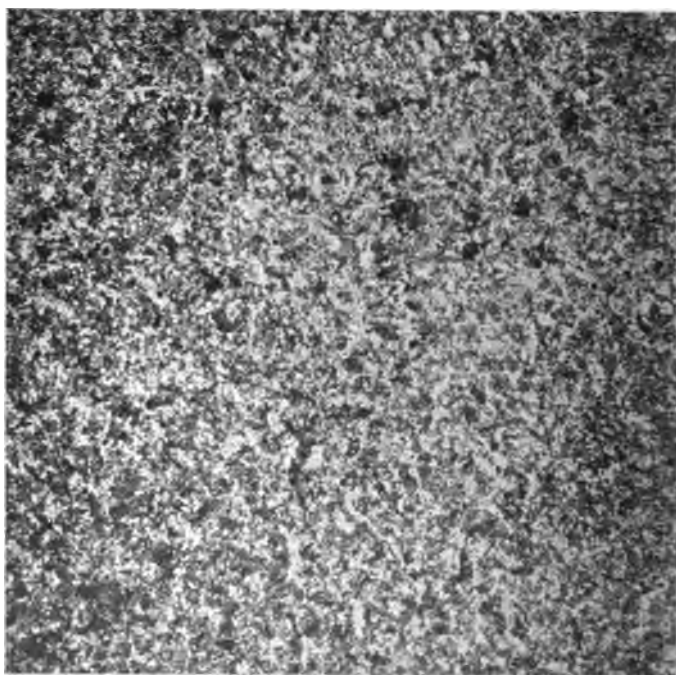


FIG. 19.—SPECIMEN A4A.

× 100.

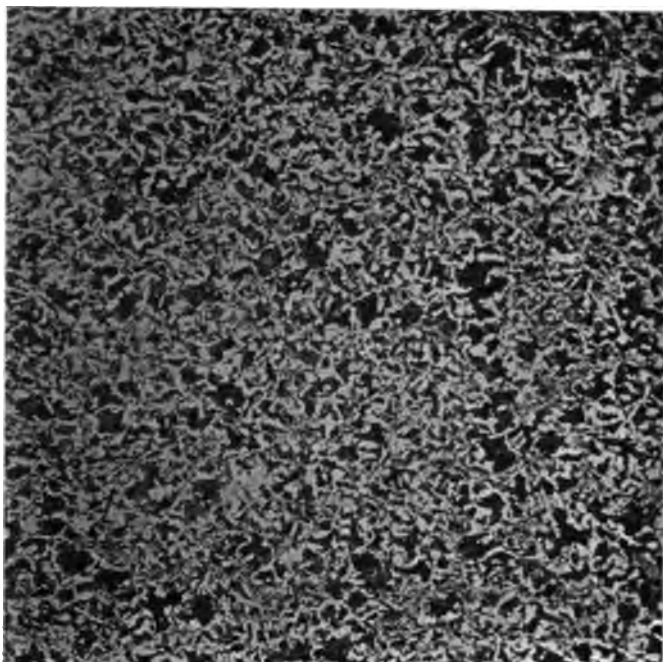


FIG. 20.—SPECIMEN A5.

× 100.

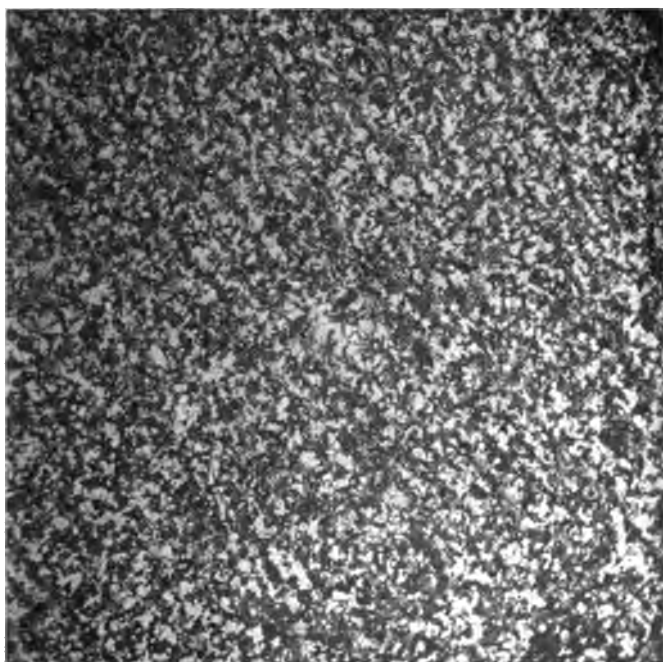


FIG. 21.—SPECIMEN A5A.

× 100.

evenly distributed. In the annealed specimens the influence of copper is not so marked as in the unannealed specimens.

With rapid or moderately rapid cooling copper appears to favor the formation of finer-grained pearlite, or, to use the words of Stead,<sup>23</sup> "more diffused carbide." This tendency increases with increasing percentages of copper. This, together with the hardening effect upon the ferrite of the copper, explains the greater hardness of copper steels. In the annealed specimens the tendency to reduce the size of the pearlite grains is not so marked.

Up to a certain limit, copper forms with iron a homogeneous alloy which is hardly distinguishable under the microscope from pure iron. Above this limit, it appears as metallic copper enveloping the grains of ferrite.

Stead<sup>24</sup> says that the maximum amount of copper which forms a homogeneous alloy with pure iron is 8.0 per cent. This alloy appears perfectly "free from copper-coloured constituent when examined under the microscope." The amount of copper which will harden the ferrite in steels will depend upon the amount of iron that remains in excess of what goes to form cementite with the carbon present, or, in other words, the amount of pure iron that is free to alloy with copper. Hence, all other conditions being equal, the greater the percentage of carbon in a steel, the less the amount of copper it is capable of taking up in solution. Accordingly, the amount of copper must be less in proportion as the carbon in the steel increases, in order that an alloy which is homogeneous is formed. The maximum amount of copper is limited for steel by its carbon content, and if the copper exceeds this maximum amount metallic copper becomes apparent in the steel. Stead<sup>25</sup> also found that in such cases, "fracture generally follows the cupreous envelopes," which apparently afford planes of weakness. Thus excess of copper would be a source of weakness rather than of strength. Breuil<sup>26</sup> says that "the presence of copper increases the quantity of pearlite in the steels, and to some extent it causes the steels to be more highly carburised, and consequently harder. With copper up to 4.0 per cent. these steels contain no free copper, that element being in solution in the iron."

Copper, in fact, acts in a two-fold manner, as has been previously noted: 1. It tends to distribute the carbide more evenly, thus tending to produce a finer-grained structure. 2. It hardens the ferrite by forming an iron-copper alloy which is harder than pure iron.

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<sup>23</sup> *Journal of the Iron and Steel Institute*, vol. lx. (1901, II), p. 119.

<sup>24</sup> *Idem*, p. 112.

<sup>25</sup> *Idem*, p. 112.

<sup>26</sup> *Idem*, vol. lxxiv. (1907, II), p. 41.

With increasing percentages of copper, according to various authorities, more and more metallic copper makes its appearance, starting first with fine films surrounding the grains and as filaments traversing the crystals of ferrite. This becomes more and more obvious with increasing copper content until it takes the form of globules which are mechanically suspended in the solid metal.

According to Stead,<sup>27</sup> the formation of these globules is also in some measure dependent upon the rate of solidification, being highest when rapidly cooled and lowest when slowly cooled. This produces heterogeneity in the structure of the mass.

According to Burgess and Aston,<sup>28</sup> the structure of copper steels "is a fine pearlite, with a fibrous cementite which is liberated with increasing copper." This explains the increasing hardness. The hardness does not result through a lowering of the points of transition.

The same view is also held by Wedding.<sup>29</sup>

*Critical Points of the Forged Bars.*—The critical points were determined upon specimens, cut from the larger bars, by means of a Le Chatelier thermo-couple and a Siemens-Halske galvanometer of the suspension type. The time interval was taken for each tenth of a millivolt, by means of two stop watches. The curves for the eight specimens are shown in Fig. 22.

One long arrest is noticeable in each, corresponding to  $Ar_1$ , or the recalescence point. The point  $Ar_1$  is lowered from  $736^\circ \pm 5^\circ$  C. in the steel containing no copper to  $644^\circ \pm 5^\circ$  C. in the steel containing 4.512 per cent. of copper. The points  $Ar_2$  and  $Ar_3$  are obscure in all the curves. This may be attributed to the percentage of carbon contained in the steel, as these three points are practically coincident in steels containing more than 0.30 per cent. of carbon.

Breuil<sup>30</sup> says that "copper lowers the recalescence point of steels, but does not lower it below  $550^\circ$  C." Müller<sup>31</sup> found that the arrest points of iron are lowered from  $60^\circ$  to  $80^\circ$  by the presence of copper. This explains why a steel containing copper is more readily hardened than one not containing that element, and in this respect the effect of copper resembles that of carbon, though to a less extent.

*Tensile Tests.*—Tensile tests were made upon: 1. Steel as forged, for which test pieces were turned from the forged bars. 2. Steel annealed. Eight pieces, in the rough before turning, were annealed

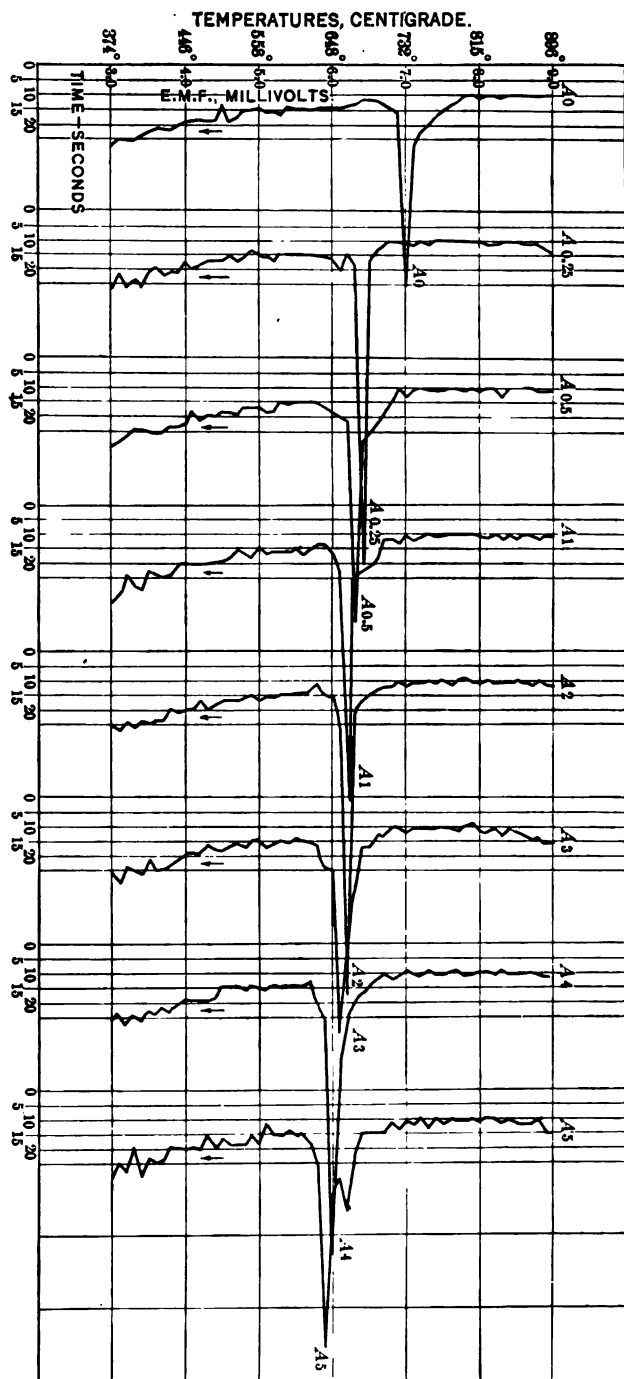
<sup>27</sup> *Journal of the Iron and Steel Institute*, vol. lx. (1901, II), p. 115.

<sup>28</sup> *Transactions of the American Electrochemical Society*, vol. xvi., p. 246 (1909).

<sup>29</sup> *Stahl und Eisen*, vol. xxvi., No. 23, p. 1444 (Dec. 1, 1906).

<sup>30</sup> *Journal of the Iron and Steel Institute*, vol. lxxiv. (1907, II), p. 13.

<sup>31</sup> *Stahl und Eisen*, vol. xxvi., No. 24, p. 1493 (Dec. 15, 1906).





in a gas furnace in a sealed muffle so as to exclude air so far as possible. The temperature was raised very slowly to avoid local overheating. Finally, after two hours the maximum temperature of  $820^{\circ}$ , as measured by a Le Chatelier thermo-couple, was reached. The eight bars were all annealed at the same time, so that each bar was subjected to exactly the same conditions. The bars were then allowed to cool in the furnace over night. The test pieces for the second series of tests were turned from this annealed steel. The test pieces were of the shape and had the dimensions shown in Fig. 23. The diameter was measured accurately three or four times at different points with a micrometer gauge and the mean of these results was taken. An electrically driven 100,000-lb. Tinius Olsen testing machine was used for pulling the bars. Photographic views of the test pieces after fracture are shown in Figs. 24 and 25.

We have taken the elastic limit as being the point where the test piece begins to show a permanent set, as indicated by the drop of the beam, without any increase of stress. Ultimate strength has been

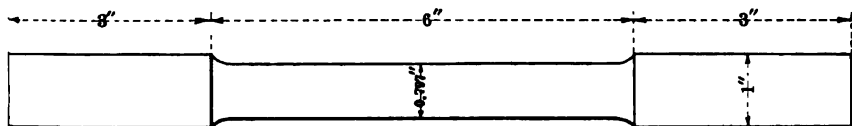


FIG. 23.—SHAPE AND DIMENSIONS OF TEST PIECES.

taken as being the maximum stress which the test piece sustains without breaking, and the ultimate breaking strength as the actual pressure exerted upon the test piece at the moment of rupture. Elongation was measured on 5 in. Reduction in area was measured at the point of fracture.

Table III gives the results for the elastic limit, ultimate strength, breaking strength, elongation, and reduction in area for both the annealed and the unannealed specimens.

The elastic limit in both the annealed and the unannealed specimens increased steadily with increasing percentages of copper. Reference to the curves, Fig. 26, shows that in the case of the annealed steels, from A0 to A0.25, the increase in elastic limit is rather rapid and then it becomes more gradual and more regular. From A1 to A5 the curve becomes practically a straight line. The increase in the elastic limit is greater in the forged specimens than in those annealed. Although the carbon content of A4 is somewhat lower than that of A0 and that of A5 is about the same, yet the elastic limit in the case of A4 is increased more than 100 per cent. and in A5 a still greater amount.



FIG. 24.—UNANNEALED TEST PIECES AFTER FRACTURE.

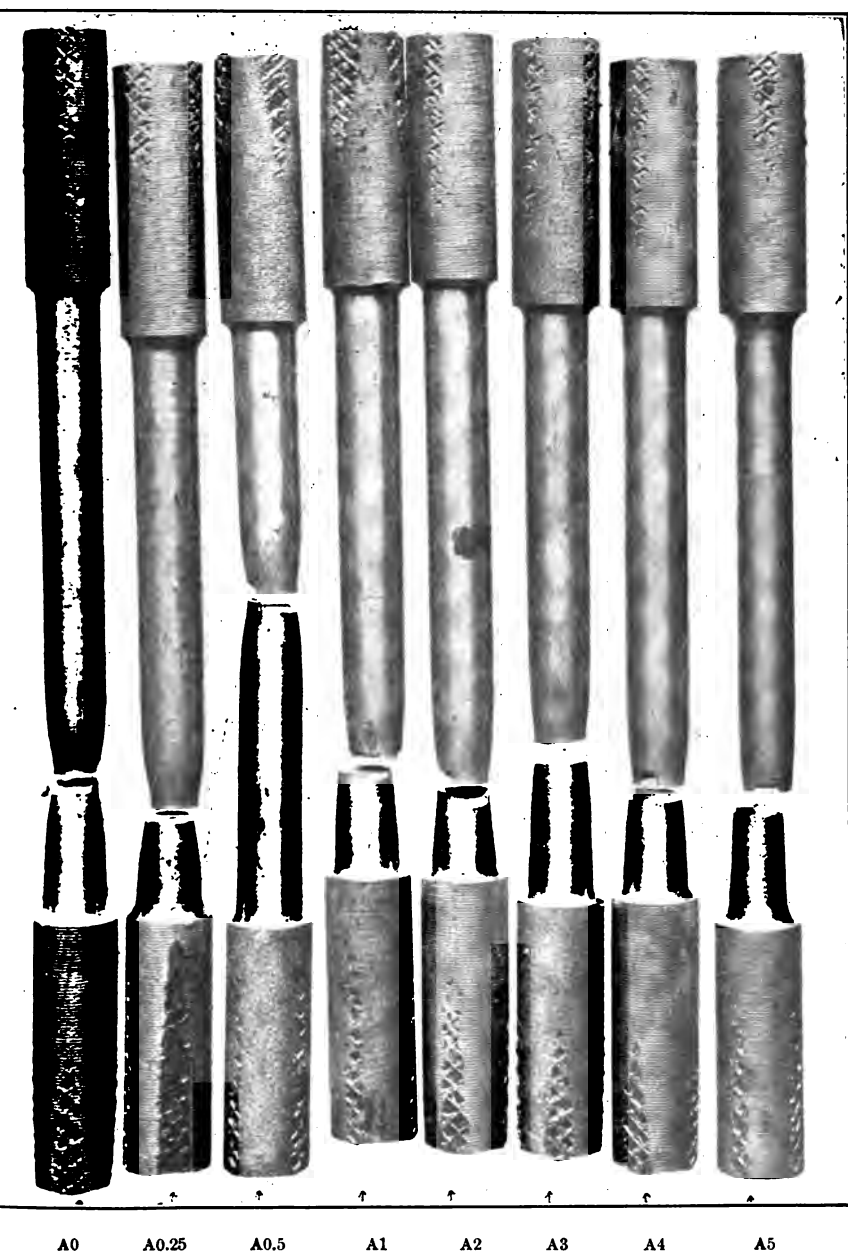


FIG. 25.—ANNEALED TEST PIECES AFTER FRACTURE.

TABLE III.—*Results of Physical Tests of Steel as Forged and After Annealing.*

| Unannealed.                 |                      |                                              |                                                     |                                     |                                    |                                                     |
|-----------------------------|----------------------|----------------------------------------------|-----------------------------------------------------|-------------------------------------|------------------------------------|-----------------------------------------------------|
| Mark.                       | Copper.<br>Per Cent. | Elastic Limit.<br>Pounds per<br>Square Inch. | Ultimate<br>Strength.<br>Pounds per<br>Square Inch. | Elongation<br>on 5 In.<br>Per Cent. | Reduction of<br>Area.<br>Per Cent. | Breaking<br>Strength.<br>Pounds per<br>Square Inch. |
| A0.....                     | 0.0                  | 51,800                                       | 86,700                                              | 20                                  | 33.2                               |                                                     |
| A0.25.....                  | 0.165                | 53,800                                       | 99,500                                              | 10                                  | 8.1                                |                                                     |
| A0.5.....                   | 0.498                | 60,300                                       | 99,000                                              | 17.5                                | 21.7                               |                                                     |
| A1.....                     | 0.846                | 60,300                                       | 97,400                                              | 20                                  | 29.3                               |                                                     |
| A2.....                     | 1.857                | 84,000                                       | 120,660                                             | 10                                  | 4.0                                |                                                     |
| A3.....                     | 2.773                | 94,600                                       | 124,300                                             | 10                                  | 12.8                               |                                                     |
| A4.....                     | 3.574                | 106,500                                      | 111,900                                             | 2.5                                 | 0.804                              |                                                     |
| A5.....                     | 4.512                | 114,400                                      | 134,000                                             | 2.5                                 | 3.64                               |                                                     |
| Same as Ultimate Strength.  |                      |                                              |                                                     |                                     |                                    |                                                     |
| Showed flaw in center.      |                      |                                              |                                                     |                                     |                                    |                                                     |
| Annealed.                   |                      |                                              |                                                     |                                     |                                    |                                                     |
| A0.....                     | 0.0                  | 39,000                                       | 75,200                                              | 25                                  | 54.2                               | 62,000                                              |
| A0.25.....                  | 0.165                | 48,300                                       | 98,500                                              | 16.25                               | 48.25                              | 80,600                                              |
| A0.5.....                   | 0.498                | 49,000                                       | 94,000                                              | 20                                  | 31.4                               | 87,900                                              |
| A1.....                     | 0.846                | 55,000                                       | 87,150                                              | 15                                  | 37.6                               | 79,400                                              |
| A2.....                     | 1.857                | 61,700                                       | 96,600                                              | 13.7                                | 37.9                               | 83,350                                              |
| A3.....                     | 2.773                | 66,000                                       | 80,000                                              | 16.35                               | 38.4                               | 84,300                                              |
| A4.....                     | 3.574                | 68,000                                       | 99,980                                              | 16.25                               | 37.0                               | 90,760                                              |
| A5.....                     | 4.512                | 74,200                                       | 110,000                                             | 17.5                                | 43.8                               | 85,800                                              |
| Showed flaw after breaking. |                      |                                              |                                                     |                                     |                                    |                                                     |

The ultimate strength curve, Fig. 27, rises with the increase in the percentage of copper, and up to A2 the general trend of the curves for both the annealed and the unannealed specimens is the same; at A1 there is a marked depression, due to a flaw in the center of the test piece. The break at A3 on the annealed curve is rather unexpected and appears to be abnormal, but it may be due to the fact that this specimen has the lowest carbon content of the whole series. A0.25 gives a better ultimate strength in the unannealed condition than A0.5, but the latter gives a higher value than the former although the carbon content of A0.25 is greater than that of A0.5 by nearly 0.1 per cent. A1 is appreciably lower in carbon than its predecessors and hence the depression on both the curves at this point. The behavior of A5 unannealed is remarkable. It gives very satisfactory tests despite the fact that the test piece had a flaw at the center.

In general, our results show quite close agreement with those of other recent investigators. Within the limits investigated the ultimate strength appears to increase almost in direct proportion to the amount of copper present. The ultimate strength of A0 unannealed was 86,700 lb. per square inch, while A5 gave 134,000 lb. per square inch—an increase of more than 50 per cent. In the annealed specimens the minimum ultimate strength is 75,200 lb. per square inch in A0, rising to 110,000 lb. per square inch in A5. This shows an increase of 50 per cent.

The elongation, Fig. 28, falls abruptly from A0 to A0.25 and then increases in A0.5. A1, untreated, has a better elongation than A0.5, but this is not strictly comparable on account of the unavoidable difference in the temperatures at which the specimens were forged.

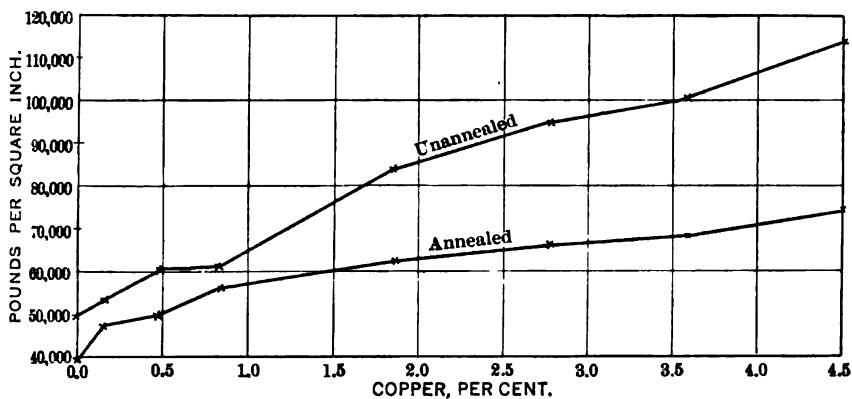


FIG. 26.—ELASTIC LIMIT CURVE.

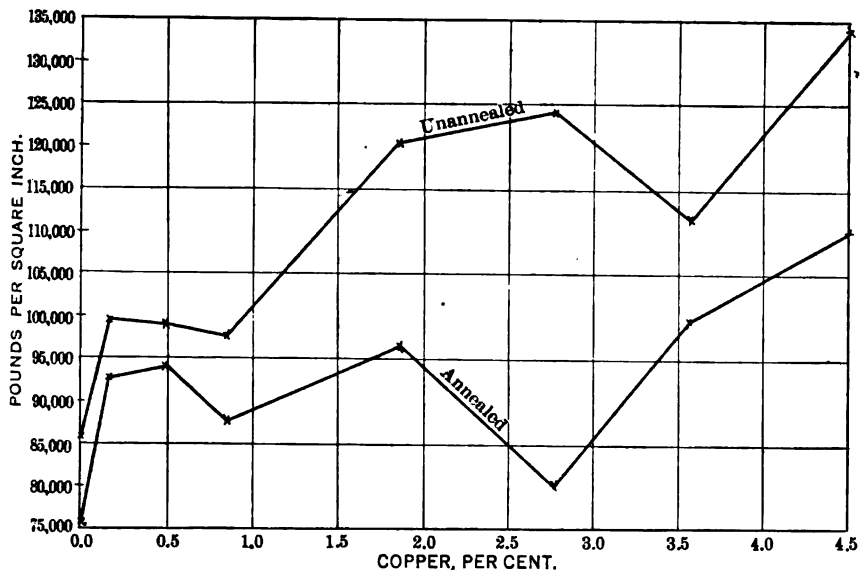


FIG. 27.—ULTIMATE STRENGTH CURVE.

The minimum elongation in the annealed series takes place at A2, after which it increases quite steadily. With the unannealed specimens the minimum elongation occurs at A4 and A5 and the general trend of the curve shows a gradual decrease of elongation, which indicates

that the steel becomes more brittle as the proportion of copper increases. In the annealed specimens the minimum elongation, 13.7 per cent., was with A2. A5, containing 4.512 per cent. of copper shows a much better elongation, 17.5 per cent.

Examination of the results for the reduction of area of the unannealed specimens does not lead to any definite conclusion. With the annealed specimens the reduction of area decreases up to A0.5, and above that point increases and finally reaches 43.8 per cent. in A5.

With the unannealed specimens the actual breaking strength in all cases was the same as the ultimate strength. The actual breaking strength in the case of the annealed specimens shows a regular in-

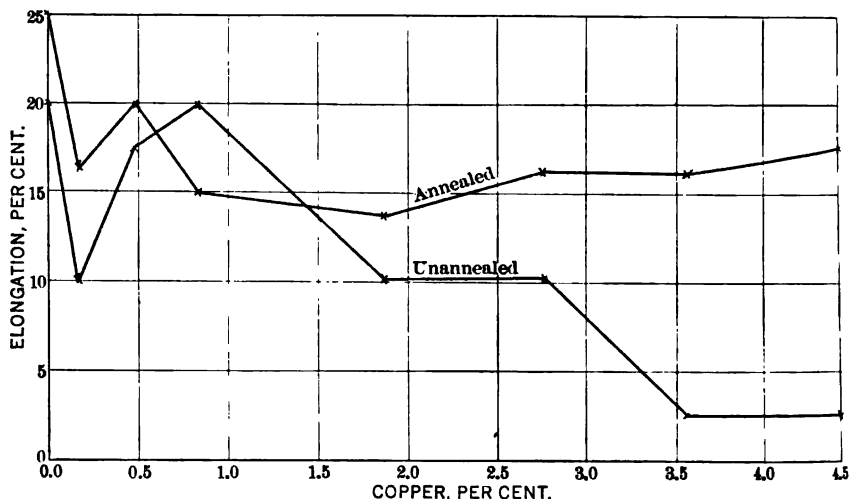


FIG. 28.—ELONGATION CURVE.

crease with increase of copper, except with A1, which, on account of a flaw in the center, gave a lower value than is to be expected. A3 gave a lower result than A2, probably on account of the lower percentage of carbon.

A5 shows the highest elastic limit and ultimate strength, both annealed and unannealed. The elongation and reduction of area in the annealed condition are satisfactory, although they are not so good in the unannealed condition. A4, annealed, ranks second in the series in elastic limit, ultimate strength, and breaking strength. It also shows a good elongation and reduction of area, but, as might be expected, it has a lower ultimate strength in the unannealed condition than A2 and A3. It shows the minimum elongation and reduction

of area. Breuil's<sup>32</sup> 4 per cent. copper specimen corresponds rather closely to A5 of our series.

For the purpose of comparison with copper steel, a number of results of tensile tests upon the alloy steels already in very general use are of interest.

Howe<sup>33</sup> gives the following results upon one of the hardest brands of Brooklyn chrome steel (chromium, 0.38; combined carbon, 0.90; manganese, 1.89; silicon, 0.03; tungsten, 0.98 per cent.):

| Tensile Strength.<br>Pounds per Square Inch. | Elongation.<br>Per Cent. | Reduction of Area.<br>Per Cent. |
|----------------------------------------------|--------------------------|---------------------------------|
| 134,000                                      | 2                        | 0                               |

Döhlen<sup>34</sup> (chromium, 0.50; combined carbon, 0.91 per cent.):

| Tensile Strength.<br>Pounds per Square Inch. | Elongation.<br>Per Cent. | Reduction of Area.<br>Per Cent. |
|----------------------------------------------|--------------------------|---------------------------------|
| 122,300                                      | .....                    | 15.7                            |

Blair and Smith<sup>35</sup> (chromium, 0.38; combined carbon, 0.84; graphite, 0.01; manganese, 0.22; silicon, 0.09 per cent.):

| Tensile Strength.<br>Pounds per Square Inch. | Elongation.<br>Per Cent. | Reduction of Area.<br>Per Cent. |
|----------------------------------------------|--------------------------|---------------------------------|
| 110,572                                      | .....                    | .....                           |

This specimen of chrome steel has about the same tensile strength as A5 annealed.

Manganese steel, forged.—Hadfield<sup>36</sup> (carbon, 1.60; silicon, 0.26; manganese, 19.10; phosphorus, 0.09 ±; sulphur, 0.06 ± per cent.):

| Natural State.                               |                          | Water Toughened.                             |
|----------------------------------------------|--------------------------|----------------------------------------------|
| Tensile Strength.<br>Pounds per Square Inch. | Elongation.<br>Per Cent. | Tensile Strength.<br>Pounds per Square Inch. |
| 116,480                                      | 1                        | 132,160                                      |

Nineteen per cent. manganese steel with 1.6 per cent. of carbon, quenched in water, has less tensile strength than A5 copper steel, forged.

Nickel steels.—Riley<sup>37</sup>:

<sup>32</sup> *Journal of the Iron and Steel Institute*, vol. lxxiv. (1907, II), p. 17.

<sup>33</sup> *Metallurgy of Steel*, p. 76 (1890).

<sup>34</sup> Ledebur: *Handbuch*, p. 261; also Howe: *Metallurgy of Steel*, p. 76 (1890).

<sup>35</sup> Report of U. S. Board to Test Iron, vol. ii., p. 590; also Howe: *Metallurgy of Steel*, p. 76 (1890).

<sup>36</sup> *Journal of the Iron and Steel Institute*, vol. xxxiii. (1888, II), Excerpt *Proceedings of the Institution of Civil Engineers*, vol. xciii. (1888) p. 40 et seq.; also Howe: *Metallurgy of Steel*, p. 361 (1890).

<sup>37</sup> *Engineering*, vol. xlvii., p. 574 (May 17, 1889); also Howe: *Metallurgy of Steel*, p. 370 (1890).

| Nickel.<br>Per Cent. | Carbon.<br>Per Cent. | Manganese.<br>Per Cent. | Tensile Strength,<br>Rolled,<br>Pounds per<br>Square Inch. | Elastic Limit,<br>Rolled,<br>Pounds per<br>Square Inch. | Elongation<br>on 4 in.<br>Per Cent. | Contraction,<br>Rolled,<br>Per Cent. |
|----------------------|----------------------|-------------------------|------------------------------------------------------------|---------------------------------------------------------|-------------------------------------|--------------------------------------|
| 1.0                  | 0.42                 | 0.58                    | 129,024                                                    | 71,904                                                  | 11                                  | 24                                   |
| 5.0                  | 5.0                  | 0.34                    | 116,480                                                    | 69,664                                                  | 15.6                                | 14                                   |

Tungsten steel.—Howe<sup>38</sup> (Mushet's Special: tungsten, 7.81; carbon, 1.99; silicon, 0.09; manganese, 0.19 per cent.):

| Tensile Strength.<br>Pounds per Square Inch. | Elongation.<br>Per Cent. |
|----------------------------------------------|--------------------------|
| 146,400                                      | 0                        |

**Hardness.**—Below are given the tests for hardness as indicated by the Shore scleroscope upon the unannealed specimens:

| Steel.      | Hardness. | Steel.   | Hardness. |
|-------------|-----------|----------|-----------|
| A0 .....    | 28        | A2 ..... | 37        |
| A0.25 ..... | 31        | A3 ..... | 37        |
| A0.5 .....  | 29        | A4 ..... | 40        |
| A1 .....    | 28        | A5 ..... | 43        |

For the purpose of comparison the hardnesses of other well-known steels as indicated by this instrument are given.

|                                         | Annealed. | Hardened. |
|-----------------------------------------|-----------|-----------|
| Mild steel, 0.15 per cent. carbon ..... | 22        | 30-46     |
| Tool steel, 1.0 per cent. carbon .....  | 30-35     | 40-50     |
| Vanadium steel .....                    | 35-45     | .....     |
| Chrome-nickel steel .....               | 47        | 60-95     |
| High-speed steel .....                  | .....     | 70-105    |

A rough qualitative test of the hardness of our copper steels was obtained by observing their behavior while being sawed and turned. In general, the unannealed specimens seemed to increase in hardness in proportion to the percentage of copper present. The hardening effect of the copper was not very marked in the annealed specimens, all of which seemed to work about the same in the lathe.

The hardening effect of copper has been observed by all investigators, both early and recent. The hardening effect of copper upon steel, as has already been pointed out, is due to two distinct causes:

1. It retards the formation of pearlite and hence there is more diffused cementite, thereby making the constituents of the steel finer.
2. It hardens the ferrite itself by forming with it an alloy which is harder than ferrite alone.

Stead<sup>39</sup> prepared an alloy with 8 per cent. of copper and 92 per

<sup>38</sup> *Metallurgical Review*, vol. ii., p. 441; also Howe: *Metallurgy of Steel*, p. 81 (1890).

<sup>39</sup> *Journal of the Iron and Steel Institute*, vol. ix. (1901, II), p. 113.



cent. of iron which was said to be as hard as forged steel containing 1.5 per cent. of carbon.

Roush<sup>40</sup> carried out hardness determination on two series of alloys, one with from 0.25 to 45 per cent. of nickel and the other with from 0.1 to 8.5 per cent. of copper. They were tested both as annealed and as forged. The addition of nickel gave a maximum hardness when present between 10 and 20 per cent., while the addition of up to 8 per cent. of copper to iron was said to give a gradual but irregular increase in hardness.

The term "hardness" has been used rather loosely without much scientific significance. It must be borne in mind that the hardness we are dealing with at present is different from the hardness of the mineralogist. Turner<sup>41</sup> has suggested that it be called "tensile hardness," since it closely follows the tensile tests.

It will be noted that the results which we give for hardness correspond fairly well with our tensile tests given in Table III. The Brinell tests for hardness given by Breuil<sup>42</sup> correspond with his tensile tests upon the same specimens. This agreement has been observed by several other investigators.

*Electrical, Magnetic, and Other Properties of Copper Steel.*—We were unable to investigate the electrical and magnetic properties of the series of copper steels which we made; but in connection with our other data the results of others along this line will be of interest.

Burgess and Aston,<sup>43</sup> experimenting upon the conductivity of alloys of iron and copper, found that there is no appreciable change in the conductivity of the alloy up to a copper content of 7.0 per cent. The resistance is slightly greater than that of pure iron. With alloys having more than 90 per cent. of copper the resistance is less than half that of pure iron. The presence of small amounts of iron in copper greatly lowers its conductivity. Conductivity is increased by annealing.

Fric,<sup>44</sup> who investigated the electrical properties of some of the steels made by Breuil, found that copper increased the electrical resistance but "there is a maximum resistance beyond which the resistance ceases to increase."

Stead and Wigham<sup>45</sup> give the following table for the relative resistance of cupreous and non-cupreous steels used for wire making:

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<sup>40</sup> *Journal of the Iron and Steel Institute*, vol. lxxxii. (1910, II), p. 516.

<sup>41</sup> *Idem*, vol. lx. (1901, II), p. 139.

<sup>42</sup> *Idem*, vol. lxxiv. (1907, II), p. 35.

<sup>43</sup> *Transactions of the American Electrochemical Society*, vol. xx., p. 205 (1911); also *Metallurgical and Chemical Engineering*, vol. viii., No. 2, p. 79 (Feb., 1910).

<sup>44</sup> *Journal of the Iron and Steel Institute*, vol. lxxiv. (1907, II), p. 70.

<sup>45</sup> *Idem*, vol. lx. (1901, II), p. 135.

|                  | Resistance<br>per Mile.<br>Ohms. | Relative Resistance. |           |
|------------------|----------------------------------|----------------------|-----------|
|                  |                                  | Normal.              | Cupreous. |
| A.....           | 1399.2 }                         | 100                  | 107.0     |
| B, Cupreous..... | 1499.5 }                         |                      |           |
| C.....           | 1269.3 }                         |                      |           |
| D, Cupreous..... | 1318.9 }                         | 100                  | 96.0      |
| E.....           | 1271.7 }                         |                      |           |
| F, Cupreous..... | 1267.5 }                         |                      |           |
| G.....           | 1320.0 }                         | 100                  | 95.8      |
| J, Cupreous..... | 1264.7 }                         |                      |           |
| N.....           | 1437.9 }                         |                      |           |
| X, Cupreous..... | 1580.5 }                         | 100                  | 110.0     |

In two cases copper effected an increase and in three cases a decrease in the electrical resistance. However, they were not very sure of their results. The samples investigated were No. 25 gauge copper steel wire and the conductivity was measured at 70° F.

Dillner<sup>46</sup> found that the magnetic properties of iron are not affected by 0.64 per cent. of copper, which decreases the conductivity of the iron as of other metals.

Brown,<sup>47</sup> determinations of the densities and specific heats of some alloys of iron, found that copper decreases the specific volume (reciprocal of density) about 0.0005 cc. for every 1 per cent. of added copper, but the specific volume of the alloy is not changed to any appreciable extent by further additions of copper up to about 4 per cent. Specific heat of iron with high percentages of carbon is not changed by chromium, cobalt, and copper when added separately.

#### CONCLUSIONS.

The following conclusions are given as a result of our work upon copper steel.

1. In making copper steel by the crucible process it is necessary to "kill" the metal before adding the copper, and just before pouring it is advisable to add a small amount of some deoxidizing agent.

2. In forging the ingots, containing from 0.437 to 0.605 per cent. of carbon, traces of "red-shortness" began to be shown with a copper content of 4.512 per cent. Up to this point the steel forged about like machine steel.

3. Up to 0.846 per cent. of copper our steels gave satisfactory welds. At 1.857 per cent. the weld was much weaker and above this point the steel could not be welded.

4. There appears to be a marked tendency for copper to eliminate sulphur.

<sup>46</sup> *Stahl und Eisen*, vol. xxvi., No. 24, p. 1493 (Dec. 15, 1906).

<sup>47</sup> *Scientific Transactions of the Royal Dublin Society*, p. 68, Aug. 23, 1907.

5. In the series of steels studied the segregation of copper toward the bottom of the ingot begins to be slightly noticeable with 0.846 per cent. of copper. With 2.773 per cent. of copper the segregation is more noticeable and with 4.512 per cent. of copper it is very marked.

6. The presence of small percentages of copper up to 0.493 per cent. has a most marked effect in preventing the corrosion of steel by dilute sulphuric acid. As the percentage of copper increases, the loss by corrosion increases until with 2.773 per cent. of copper the loss is greater than when the steel does not contain copper.

7. As the percentage of copper increases the structure becomes finer, due to the more even distribution of fibrous cementite. This is more apparent in the forged than in the annealed specimens.

8. The point  $A_r$  was lowered from  $730^{\circ}$  C. in the steel containing no copper to  $635^{\circ}$  C. in the steel containing 4.512 per cent. of copper.

9. The elastic limit in both the annealed and the unannealed specimens increases steadily until with 4.512 per cent. of copper it was increased more than 100 per cent. over that of steel containing no copper.

Within the limits investigated the ultimate strength appears to increase almost in direct proportion to the amount of copper present.

With the unannealed specimens the actual breaking strength in all cases was the same as the ultimate strength. The actual breaking strength in the case of the annealed specimens shows an increase with the increase of copper.

In the annealed specimens the elongation is somewhat irregular, but in general decreases up to 1.857 per cent. of copper and then increases and reaches a maximum at 4.512 per cent. of copper.

The general tendency in the annealed specimens is to decrease the elongation up to 1.85 per cent. of copper and then up to 4.512 per cent. of copper to gradually increase it. In the unannealed specimens the general tendency is to decrease the elongation throughout the series.

10. The hardness of the steel increases with increasing copper content and corresponds fairly well with the tensile tests.

#### BIBLIOGRAPHY AND SYMPOSIUM OF OPINION.

##### *Arranged Chronologically.*

1. Louis Savot (1627) [*Jour. I. and S. Inst.*, 1889, I, p. 130] stated in his book that copper made iron brittle, and mentioned the difficulties experienced by "smiths" in working iron containing copper. He referred to a still older authority, Budelius, who held that copper rendered iron incapable of being welded.
2. Jars (1774) [*Voyages Métallurgiques*, Lyons, 1774, vol. i., p. 4; also Ball and Wingham, *Jour. I. and S. Inst.*, 1889, I, p. 123] comments, "It is generally thought that copper

- is a pest for iron," but he adds that he had been told by Cramer that the quality of iron was improved by small quantities of copper, and that even 1 per cent. of copper had no deleterious effect on the welding properties of the metal.
3. Rinmann (?) [*Percy's Iron and Steel*, 1864, p. 147] strongly heated, in a blast furnace, a crucible containing a mixture of 5 parts of iron and 1 part of copper. It was hard and tough and could only be broken with difficulty. He says "it cannot be denied that the presence of copper in bar-iron causes incurable red-shortness."
  4. Faraday and Stodart (1820) [*Quart. Jour. of Science, Lit. and the Arts*, 9, p. 329, 1820; also *Philos. Trans.*, 1822, p. 286] melted steel with 2 per cent. of copper, but the quality of the metal did not appear to have improved at all.
  5. Mushet (1835) [*Phil. Mag.*, 6, 1835, p. 81] found that a 50 per cent. alloy of copper with malleable iron possessed great strength, becoming harder with an increasing percentage of iron. Steel melted with 5 per cent of copper was considerably hardened but could not be forged. He concluded as a result of his experiments that copper unites with iron more freely as the percentage of carbon decreases.
  6. Stengel (1837) [*Karsten's Archiv.*, 10, 1837, p. 714; also *Percy, Iron and Steel*, p. 151] states that a much smaller percentage of sulphur than of copper will make iron red-short and that 0.1 per cent. of sulphur is more injurious to the mechanical properties of iron than 0.75 per cent. or more of copper.
  7. Karsten (?) [*Eisenhüttenkunde*, 1, p. 498; also *Percy, Iron and Steel*, p. 148] stated that iron would take up but a very small amount of copper, which made it red-short.
  8. Longmaid (1861) [Patent No. 1863, A. D. 1861] was said to have a patent for an alloy consisting of 2.5 to 10 lb. of copper to 1 ton of iron, which was supposed to possess unusual hardness.
  9. Eggertz (1862) [*Jahres Bericht*, Wagner, 1862, p. 9; also *Percy, Iron and Steel*, pp. 149, 153; also *Howe, Met. of Steel*, p. 83] found that wrought iron containing 0.5 per cent. of copper showed only traces of red-shortness.
  10. Percy (1864) [*Percy's Iron and Steel*, 1st Ed., p. 149] who experimented with alloys of iron and copper, states that the two metals are miscible in all proportions.
  11. Willis (1880) [*Jour. I. and S. Inst.*, 1880, I, p. 93] found that 0.1 per cent. of copper did not produce any appreciable effect on the quality of steel.
  12. Wasum (1882) [*Stahl u. Eisen*, 1887, p. 193; *Jour. of the Chem. Soc.*, 1883, p. 404; *Jour. I. and S. Inst.*, 1882, I, p. 369; also *E. and M. Jour.*, 1884, vol. xxxviii, p. 5] made experiments in which he investigated the effect of copper alone, sulphur alone, and the two together upon steel. He concluded that, up to 0.862 per cent., copper did not develop a trace of red-shortness. Copper and sulphur combined did not appear to produce red-shortness unless the percentage of sulphur is sufficient itself to cause it. He regarded from 0.15 to 0.16 per cent. as the limit for sulphur.
  13. Choubley (1884) [*Bulletin de la Société de l'Industrie Minière*, xiii., 205; *Jour. I. and S. Inst.*, 1884, I, p. 248; also *E. and M. Jour.*, 1884, vol. xxxviii, p. 5] confirms the observation of Wasum on the rolling qualities of copper steel, and found that even 1 per cent. of copper in the absence of sulphur did not produce red-shortness.
  14. Holtzer (1889) [*Howe, Met. of Steel*, p. 368; also *E. and M. Jour.*, 1890, vol. I, p. 426] exhibited some copper steels at the Paris Exhibition of 1889 containing from 3 to 4 per cent. of copper. They were remarkable for extremely high elastic limit, especially of the hardened bars, which went up to 142,228 lb. per sq. inch.
  15. Brustlein (1889) [*Howe, Met. of Steel*, p. 368; also *E. and M. Jour.*, 1890, vol. I, p. 426] says that steels with more than 1 per cent. of copper were decidedly red-short and had no future, that copper did not make a thorough mixture with steel, and that it favored the formation of blow-holes.
  16. Ball and Wingham (1889) [*Jour. I. and S. Inst.*, 1889, I, p. 123; also *Jour. Franklin Inst.*, July, 1890, p. 35] observed in the course of their experiments that the presence of carbon seemed to favor the more intimate mixture of copper with iron. Some of their specimens with small percentages of carbon and copper worked well both cold and hot. They found that copper makes iron and steel extremely hard, and that

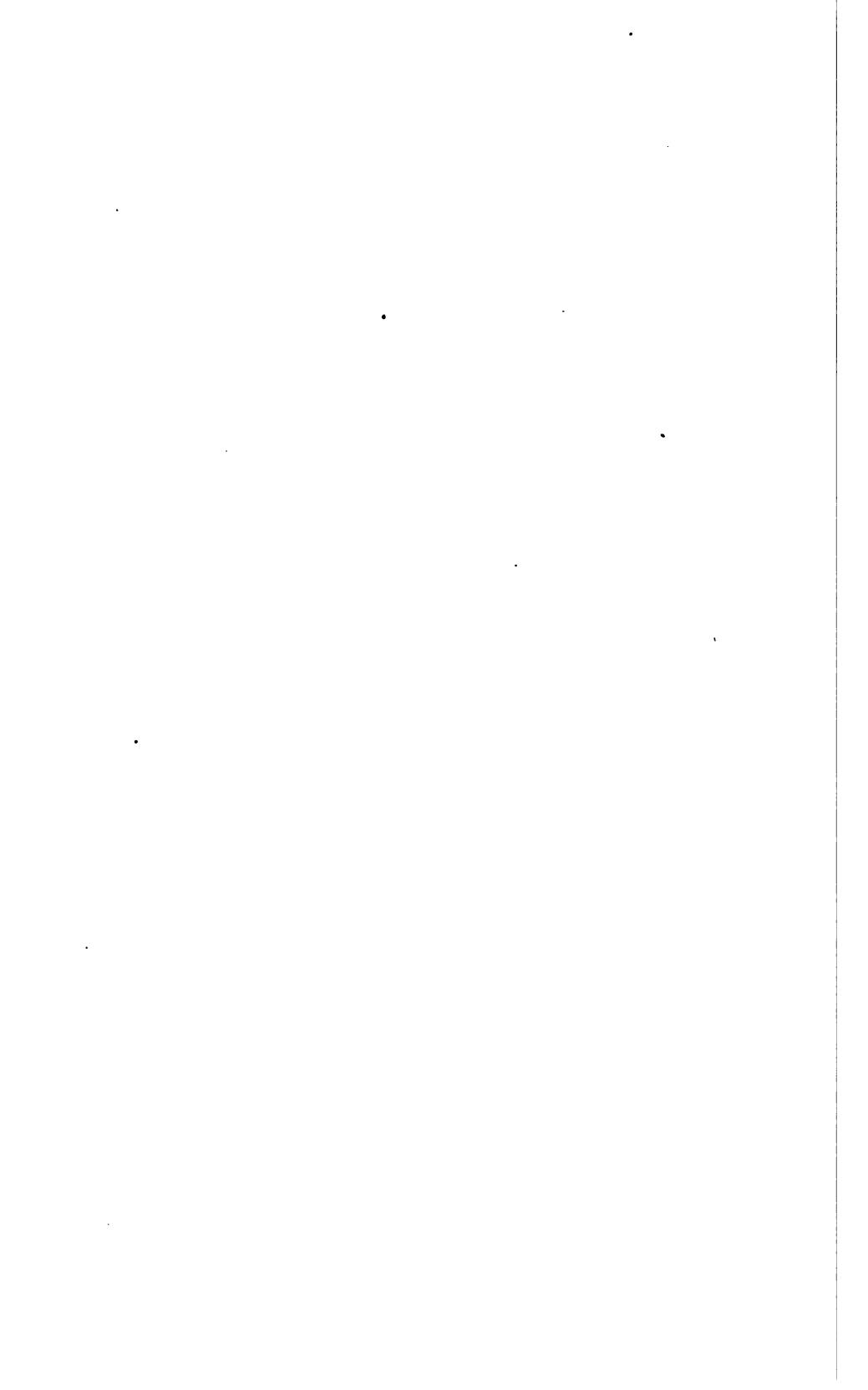
"within certain limits copper does not prejudicially affect the mechanical properties of steel."

17. Riley (1890) [*Jour. I. and S. Inst.*, 1890, I, p. 123] observes that copper is not really alloyed with iron, but exists disseminated throughout the metal. If aluminum is used in making the alloy, a perfect mixture is obtained.
18. Schneider (1890) [*E. and M. Jour.*, 1890, vol. I., p. 426] obtained a patent upon a method of alloying copper with steel. His alloys were remarkable for great strength, tenacity, and malleability. They were claimed to be specially useful in the manufacture of ordnance, armor plate, gun tubes, projectiles, etc. These alloys contained between 5 and 20 per cent. of copper.
19. Bauerman (1890) [*Treatise on Met. of Iron*, p. 50, ed. 1890] says that copper and iron can be melted together in all proportions, but doubts the formation of a homogeneous alloy.
20. Scranton (1891) [*Howe, Met. of Steel*, p. 83, ed. 1891; also Garrison, *Jour. Franklin Inst.*, Aug., 1891, p. 125], of the Scranton Steel Works, is said to be habitually manufacturing Bessemer T rails with 0.50 to 0.66 per cent. of copper which are not red-short.
21. Howe (1891) [*Met. of Steel*, p. 82, 1891] declares that iron and copper unite in all proportions, and the alloys of iron with small amounts of copper are said to be homogeneous. He also states that the effect of copper resembles that of sulphur to render steel red-short and incapable of being welded.
22. Garrison (1891) [*Jour. Franklin Inst.*, Aug., 1891, p. 121] hopes for a very extensive use of copper steel in the arts and manufactures in view of its high elastic limit combined with a considerable elongation. He says that 0.5 per cent. of copper will alloy with steel without difficulty, but it is doubtful if 10 per cent. would make a homogeneous alloy.
23. Hogg (1893) [*Jour. of Soc. of Chem. Industry*, vol. xii, p. 236; also *Jour. I. and S. Inst.*, 1893, I, p. 388] found that copper does not tend to segregate in steel.
24. Arnold (1894) [*Jour. I. and S. Inst.*, 1894, I, p. 107] had no difficulty in hammering an ingot with 0.1 per cent. of carbon and 1.8 per cent. of copper. He states that copper has a greater influence than manganese in raising the elastic limit.
25. Colby (1899) [*Jour. I. and S. Inst.*, 1900, I, p. 412; also *Iron Age*, Nov. 9, 1899, pp. 10-11] states that small percentages of copper have no deleterious effect upon steel. He made propeller shafts for U. S. battleships and gun tubes, by forging steel containing copper, which fulfilled the specifications of the government. The tensile strength was not less than 75,000 lb. per square inch, combined with an elastic limit of not less than 36,000 lb. per square inch and an elongation of 20 per cent. in length of 2 in. It stood bending fairly well and could be successfully welded. The copper content of his steel was 0.565 per cent.
26. Williams (1900) [*Iron Age*, Nov. 29, 1900; also *E. and M. Jour.*, vol. lxx., 1900, p. 667] experimented upon the atmospheric corrosion of copper steel and came to the conclusion that the loss due to weathering decreases with the increase of the copper content.
27. Lipin (1900) [*Stahl u. Eisen*, vol. xx., pp. 536-541 and 583-590; also *Jour. I. and S. Inst.*, 1900, II, p. 551] observed that copper increases the fluidity of steel and makes it more and more crystalline at the fracture. He found steel to be red-short when the copper reached 4.7 per cent. He is of the opinion that tool steel may contain copper up to 1 per cent. and suggests the quenching of cupreous tool steels in oil instead of water in the process of hardening. He concludes that the presence of copper need not cause apprehension, although there may not be any advantage in its presence. He also found that as the percentage of carbon increased, the proportion of copper must be reduced, otherwise the metal cracked during working.
28. Ruhfus (1900) [*Stahl u. Eisen*, vol. xx., p. 691; also *Jour. I. and S. Inst.*, 1900, II, p. 554] gives from 0.4 to 0.5 per cent. of copper as the limit beyond which red-shortness becomes evident.

29. Stead and Evans (1901) [*Jour. I. and S. Inst.*, 1901, I, p. 89] concluded as the result of their investigations that "Copper has no more right to have the character of making steel red-short than carbon," that "between 0.5 and 1.3 per cent copper had no deleterious effect on either the hot or cold property of steel," and that "a very large amount (2.0 per cent.) makes the steel more liable to be over-heated" In small quantities it slightly raises the tenacity and the elastic limit.
30. Stead and Wigham (1901) [*Jour. I. and S. Inst.*, 1901, II, p. 122] experimenting on the effect of copper on steel for wire making, found that 1.28 per cent. of copper has apparently no effect when the copper content is low. They think that the copper-iron portion of the steel is distributed unequally and may have more deleterious effect on the mechanical properties of the steel in proportion as the carbon content is higher. They are of the opinion that copper in higher-carbon steel for wire making should be avoided. They also found that copper helps to retard the corrosion in steels.
31. Stead's (1901) [*Jour. I. and S. Inst.*, 1901, II, p. 104] exhaustive research on copper and iron alloys proves that the amount of carbon present in the iron determines the amount of copper that can be alloyed with it; that some of the copper is held mechanically suspended in the alloy in the form of globules, and this depends on the rate of solidification of the alloy. He concludes that "Copper in foundry iron need not be feared, as its only effect appears to be that of raising its tenacity."
32. Wigham (1906) [*Jour. I. and S. Inst.*, 1906, I, p. 222]. In America and Germany steels which contain appreciable amounts of copper have been used for different purposes.
33. Wigham (1906) [*Jour. I. and S. Inst.*, 1906, I, p. 222] believes that copper is very difficult to alloy with steel. In steel it is not of practical value to use more than 0.6 per cent., and that copper up to 0.25 per cent. is no disadvantage in the making of the best classes of steel wire.
34. Pfeiffer (1906) [*Metallurgie*, vol. iii., pp. 281-287; also *Jour. I. and S. Inst.*, 1906, IV, p. 908] thinks that copper remains suspended in fine particles throughout the mass of metal and that copper is liable to be injurious when it exists in sufficient quantities to cause non-uniformity in the structure of the metal.
35. Dillner (1906) [*Stahl u. Eisen*, Dec., 1906; *Bihang till Jernkontorets Annaler*, 1906, pp. 357-378; also *Kungl. Tekniska Högskolans Material-pröfningsanstalt*, 1896-1906, Stockholm, Lindståhl] observed that 0.62 per cent. of copper is entirely harmless in a soft steel, although it increases the brittleness of a hard steel. Steel containing 1 per cent. of carbon and more than 3 per cent. of copper is not capable of being rolled.
36. Müller (1906) [*Wedding, Stahl u. Eisen*, Dec., 1906] established the fact that iron containing 0.14 per cent of carbon was capable of alloying in all proportions with copper. He also found that within certain limits copper acts beneficially; it diminishes the malleability, also the tendency to red-shortness. It raises the fusibility and the fluidity and increases the hardness and tensile strength. He also found that the absorption of carbon takes place more energetically with increasing percentage of copper. Iron originally rich in carbon is not in condition to receive more than 4.75 per cent. of copper.
37. Campbell (1907) [*The Manuf. and Prop. of Iron and Steel*, 1907, p. 358] says that most of the Bessemer and open-hearth steels mentioned in his book contained from 0.3 to 0.5 per cent. of copper. "This will be sufficient proof that the best steel may contain up to 1.0 per cent. of copper without being seriously affected, but if at the same time sulphur is high, say 0.08 to 0.1 per cent., the cumulative effect is too great for molecular cohesion at high temperatures and it cracks in rolling." He found no difference in the ultimate strength of steels with high or low copper content. "The high copper gives a slightly higher elastic ratio which is a benefit and a better elongation and reduction of area.
38. Breuil (1907) [*Jour. I. and S. Inst.*, 1907, II, p. 1] mentions that Vanderheyem, Engineer of the Paris, Lyons, and Mediterranean Railway Co., had "observed the favorable influence exerted by the presence of copper on certain steels, notably those employed for the axles of railway vehicles."

39. Breuil (1907) [*Jour. I. and S. Inst.*, 1907, II, pp. 45-46; also *Comptes Rendus*, vol. cxlii., pp. 1421-1424] concludes his long and exhaustive research by the following statement: "copper steel remains commercially serviceable up to about 4 per cent. of copper." The property of satisfactory rolling is sacrificed with percentages of copper exceeding 4 per cent. Copper steels have greater tensile strength with increasing amounts of copper and this is most noticeable in the case of mild steels. Copper steels equal, from the point of view of tensile strength, nickel steels, and would be less costly than the latter. Copper steels are not more brittle than nickel steels. "What is particularly advantageous is that while hardening the steel the presence of copper does not render it brittle. It confers upon it a very fair degree of elasticity while leaving the elongation good, thus conducing to the production of a most valuable metal."
40. Sahmen (1908) [*Zeitschrift für anorganische Chemie*, vol. lvii., pp. 1-33; also *Jour. I. and S. Inst.*, 1903, I, p. 409] holds that copper and iron are miscible in the molten condition and that there are two series of mixed crystals, from 0.0 to 3.5 per cent. and from 97.3 to 100 per cent. by weight of copper respectively.
41. Burgess and Aston (1909) [*Trans. Am. Electro-Chem. Soc.*, 1909, pp. 241-256; also *Iron Age*, vol. lxxxiv., pp. 1476-1479] conclude as the result of their investigation of the alloys of electrolytic iron and copper that hardness increases with increase of copper up to a limit of from 5 to 7 per cent. There is also increase of tensile strength with the increase of copper. The alloys up to 2 per cent. of copper forged well, at low heats, from 7 to 80 per cent. alloys—non-forgeable. Between 80 and 100 per cent. they forged at a "fair red heat." With less than 5 per cent. of copper the alloys welded easily. Burgess was inclined to believe that the copper-iron alloys were going to be rather corrodible metals.
42. Clamer (1910) [*Jour. I. and S. Inst.*, 1910, II, p. 515; *Amer. Soc. for Testing Materials*, June, 1910] found that the nickel in nickel steel may be replaced by copper without materially altering the physical properties of the metal.
43. Sargent (1912) [*Electro-Chem. and Met. Jour.*, 1910, p. 68] says that red-shortness is to be expected from additions of copper to steel in the ordinary steel making processes on account of the formation of oxides of copper.
44. Editorial (1912) [*E. and M. Jour.*, 1912, vol. xciv., p. 677]. Remarkable durability is mentioned of some rails on the New Haven railroad which upon analysis were found to contain about 0.5 per cent. of copper. Rails with 0.5 per cent. of copper have also been used on the Pennsylvania road for a long time.
45. Buck (1913) [*Jour. of Industrial and Engineering Chemistry*, June, 1913, p. 447], as the result of an elaborate investigation shows that steel containing 0.15, 0.24 and 0.34 per cent. of copper withstands atmospheric corrosion about twice as long and corrosion by dilute sulphuric acid 50 to 100 times as well as ordinary steel.
46. Burgess and Aston (1913) [*Jour. of Ind. and Eng. Chem.*, June, 1913, p. 458] investigated the corrodibility of alloys of electrolytic iron and copper. They report a high resistance to attack by acid and a low atmospheric corrosion for the whole series investigated (copper 0.089 to 7.05 per cent.).
47. Anonymous (1913) [*E. and M. Jour.*, vol. xciv., p. 1211, June 14, 1913]. "Chicago, Milwaukee & St. Paul Ry. officials say that complete reports on the 5,000 tons of steel rails, which the company ordered last year with an alloy of 0.6 per cent. copper, which were laid in various sections of the system, principally in the Northwest, show that not one broken rail has been found in the lot. This is considered a remarkable showing. The company has ordered 10,000 more tons of the same copper-steel rails, and if the result is similar, will adopt this rail as its standard."

Mr. Ray's portion of this work has been submitted in partial fulfillment of the requirements for the degree of Master of Arts at Stanford University.





ON OF THIS PAPER IS INVITED. It should preferably be presented in person at the meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, a paper in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West Street, New York, N. Y., for presentation by the Secretary or other representative of its Institute. If a special arrangement is made, the discussion of this paper will close Oct. 1, 1913, when the *Transactions* will go to press. Any discussion offered thereafter should preferably be on a new paper for publication in Vol. XLVII. (with suitable cross-references in both

## The Cleaning of Blast-Furnace Gas.

BY W. A. FORBES,\* NEW YORK, N. Y.

(New York Meeting, October, 1913.)

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### INTRODUCTORY.

In the early stages of blast-furnace practice, the gas formed in the blast-furnace escaped by the combustion of the coke used in smelting the iron. The gas was allowed to escape into the atmosphere. The light furnished

by the combustion of this gas as it reached the air was a familiar sight in the days when open-top furnaces were in vogue. As blast-furnace practice progressed, however, involving the use of hot blast and the development of power from the gas, blast-furnace construction was modified to conserve this gas for heating hot-blast stoves, raising steam under boilers, and various miscellaneous purposes.

When the use of blast-furnace gas was extended to the driving of gas engines, the necessity for thoroughly cleaning the gas became apparent, and soon the advantages of also properly cleaning the gas for use in stoves and under boilers became more fully recognized.

#### REASONS FOR GAS CLEANING.

Blast-furnace gas as it issues from the stack is laden with various amounts of a fine gritty dust composed of particles of ore, coke, and limestone. This dust has a bad effect in hot-blast stoves and under boilers, where a large proportion of the gas is ultimately consumed, as it reduces the heating efficiency of the stoves by clogging up the checker openings and chambers and by fusing with the brick-work. It reduces the efficiency of the boilers by fouling the combustion chamber and by building-up around the tubes. In both cases, the efficiency of the combustion is impaired by the presence of dust in the gas.

The presence of even small quantities of dust in the blast-furnace gas prevents its economical use in gas engines on account of the gritty dust particles cutting the pistons and cylinders of the engines, causing frequent stops for cleaning and for repairs and renewals. The separation of the dust from the gas, therefore, becomes a matter of great importance from an economical standpoint in order to obtain the best results from the gas.

Thorough cleaning of blast-furnace gas was never attempted until the gas began to be used in gas engines, when the necessity of devising methods for removing the objectionable dust became apparent. Prior to that time, each blast-furnace plant handled the dust in its own way to best suit the local conditions. Thus, in England, practically no attempt was made to remove the dust from the gas, which was allowed to issue directly from the blast furnaces into the gas mains which conveyed the dirty gas to the stoves and boilers. As these mains became clogged with dust, which condition naturally occurred at frequent intervals, the blast furnaces had to be shut down and the dust removed. The gas mains were usually laid underground, adding to the trouble and expense of cleaning, as well as the danger from gas poisoning and explosions.

## FIRST METHODS OF SEPARATION OF DUST.

many, where the advantages of using cleaned blast-furnace gas were more generally recognized than in England, attempts were made to separate the dust from the gas by various systems of scrubbing with water in the gas mains, but the resulting slime was difficult to handle, and this method was not widely followed.

It was noticed that more dust was deposited in the gas mains at points where the direction of the gas current changed, or where the pipe narrowed in diameter, and this led to the idea of dry cleaning, the introduction of dust catchers of large diameter; of cyclone separators where a centrifugal motion was imparted to the gas by the nature of its mode of entry into the apparatus; and of zig-zag scrubbers where the course of the gas was continually changed up and down.

The deposited dust could then be readily removed by means of valves in the bottom of the apparatus. Dust catchers of various types were developed, the gas entering radially or tangentially, thus facilitating dust deposition by centrifugal force. A further improvement allows the gas to enter the dust catcher tangentially at the top and to leave the dust catcher through a central pipe projecting into the dust catcher.

The basic principle of the separation of dust in these apparatus is the change of direction in the flow of the gas, together with the deceleration of the gas in the dust catchers and separators due to their large transverse sections than the gas mains.

## DUST PRODUCED BY THE BLAST FURNACES OF THE UNITED STATES STEEL CORPORATION DURING 1912.

Conditions in blast-furnace gas are more severe in the United States than in Europe on account of the larger proportion of very fine dust in the American furnaces, and on account of the harder operation of the furnaces, which causes more dust to be blown over. As an example of blast-furnace practice in the United States, during 1912, 98 of the blast furnaces of the United States Steel Corporation drew their ore requirements from the Lake Superior region. They produced 13,090,411 tons of pig iron, out of a total of 13,229 tons produced by the Steel Corporation during the year. The Lake Superior ores used, 81.5 per cent. was Mesabi ore, which is usually very fine. There were 1,291,512 gross tons of dust, of which approximately 52 per cent. of iron, separated from the gas.

The United States Steel Corporation has installed several plants for cleaning and sintering the dust separated from blast-furnace gases,

with the object of ultimately consuming all the dust in the blast furnaces. Of 1,291,512 tons of flue dust produced in 1912, 788,933 tons were returned to the furnaces without other treatment than spraying or soaking with water; 181,149 tons were converted into briquettes and sinter, and the greater part of the remaining 321,430 tons was stocked until such time as it is possible to use the material in some form or other.

#### DUST CONTENT IN GAS.

The gas leaving the usual dust catcher contains an average of from 3 to 4 grains of dust per cubic foot, and its further cleaning is accomplished in one or two principal stages, depending on the ultimate use of the gas: namely, primary cleaning and final cleaning. In primary cleaning, the gas is sufficiently cleaned for economical use in heating hot-blast stoves and for raising steam in boilers; it has been found that the best results are obtained when the dust content of the gas, after cleaning, does not exceed 0.2 grain per cubic foot. In final cleaning, the gas is sufficiently cleaned for use in gas engines, and in this case the best practice has resulted when the dust content of the gas, after cleaning, does not exceed 0.008 grain per cubic foot.

Various systems and methods are employed for accomplishing the desired results. In modern practice, the gas leaving the blast furnace is, in practically all cases, conducted through downcomer mains and then through a dust catcher of large capacity, and in some cases through two such dust catchers in series. A considerable proportion of the heavier dust is deposited at this stage. From the dust catcher the gas passes to the additional cleaning apparatus through gas mains, usually equipped with downtakes and valves for the removal of the deposited dust. The mode of treatment from this point on varies considerably, according to the opinions of the operators as to the respective merits of various systems.

#### PRIMARY DRY CLEANING.

For primary cleaning, a separation of the dust without the use of water—in other words, dry cleaning—has been in favor at many plants on account of the ability to thus conserve the sensible heat of the gas, which is lost when water is used. The fact, however, should not be lost sight of that the benefit derived from the sensible heat of the dry-cleaned gas is largely discounted by the amount of water vapor in the gas. This is especially the case with gas from blast furnaces operating with a high top temperature and using ores and coke containing much moisture existing either free or chemically combined; the water vapor affects the efficiency of the combustion of the gas.

ional benefit of dry cleaning lies in the greater facility to handle the flue dust in the dry state than in the form of slurry in the wet cleaning processes. As before stated, the principles in practically all of these dry cleaning systems depend upon the direction of the gas, a reduction in its velocity, separation of the dust by gravity and centrifugal force. The

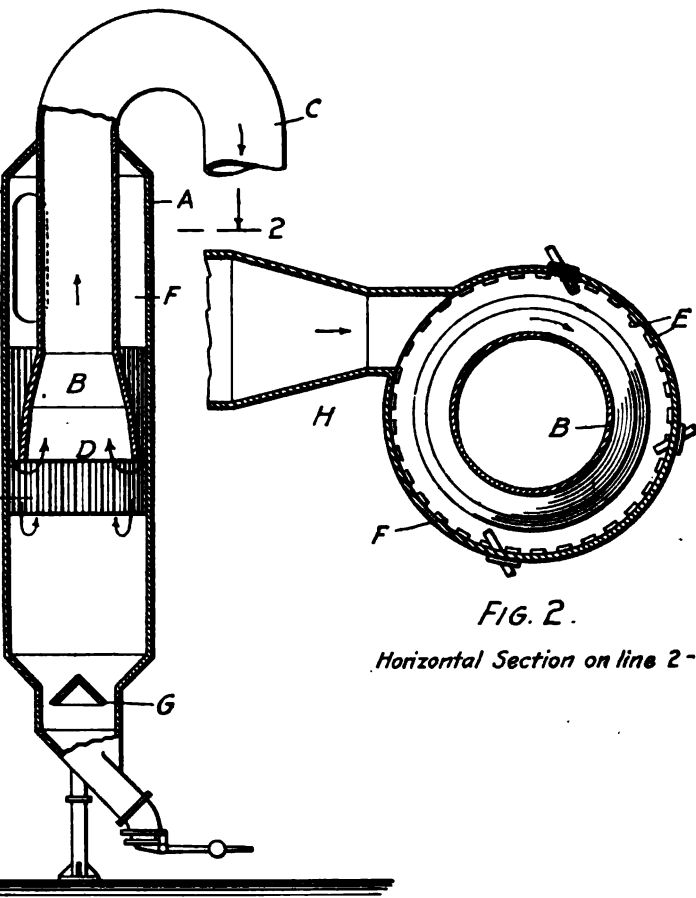


FIG. 2.

*Horizontal Section on line 2-2.*

FIG. 1

FIGS. 1 AND 2.—BRASSERT-WITTING WHIRLER.

modifications by which this separation of dust is accomplished have been derived from the so-called cyclone processes developed in Germany about 20 years ago. Some of these systems recently developed in the United States are the Brassert-Witting, the Roberts, the Kenney, and the Dyblie. A description of the Brassert-Witting whirler will illustrate the general principles of this method of cleaning.

*Brassert-Witting Whirler.*

As shown in Figs. 1 and 2, the Brassert-Witting whirler consists of a vertical outer cylindrical casing, *A*, and an inner inverted tube, *B*, which at its upper end is integral with the gas main *C*, which takes the cleaned gas away from the apparatus. This inverted tube is flared at its lower end, *D*; a number of iron or steel bars, *E*, are

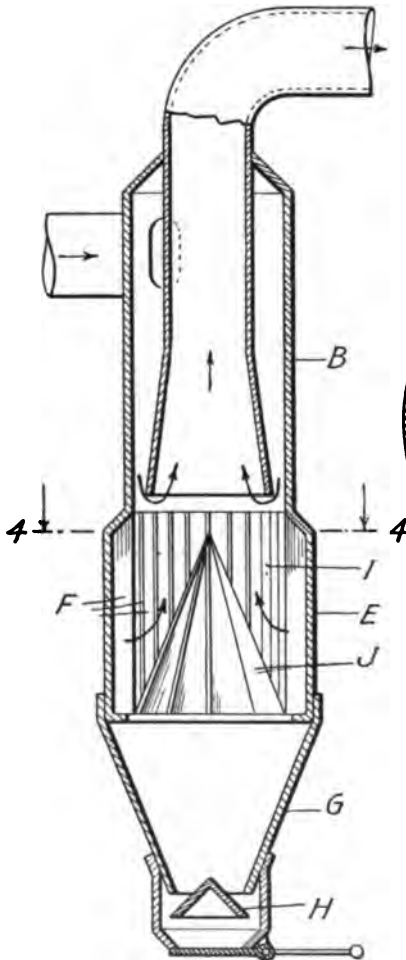


FIG. 3.

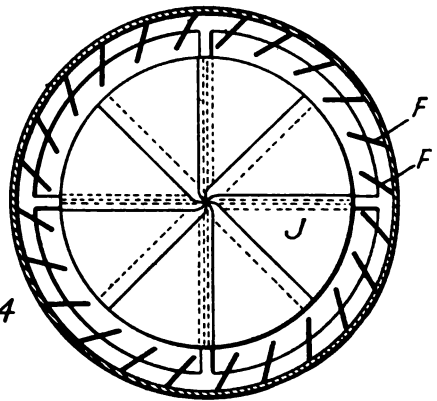


FIG. 4.

*Horizontal Section on line 4-4.*

FIGS. 3 AND 4.—BRASSERT MODIFICATION OF BRASSERT-WITTING WHIRLER.

fastened vertically around the chamber *F* and extend from a point well above the lower edge of the flared end *D* of the pipe to a point well below the lower edge of this pipe. In the lower part of the chamber *F* is placed a cone, *G*, which allows the separated dust to enter the outlet pipe.

enters the apparatus tangentially through the flue *H* and rotary whirling motion through the annular space between and the wall of the chamber *A*. On coming in contact with the bars *E* the dust is caught in the channels between these bars in position by the combined action of centrifugal force and gravity. As the gas continues to rotate within the annular chamber mentioned, its velocity is gradually increased by the flared end of the receiving pipe until when it reaches the edge of the end its velocity is at a maximum. On passing the edge, the velocity is constantly decreased, the direction of flow is changed and it passes upwardly through the flared end of the outgoing gas main *C*.

The dust which has been caught in the channels between the baffle plates falls vertically into the bottom of the chamber, past the cone of the outlet pipe, whence it is removed as desired.

#### *Brassert Modifications of Brassert-Witting Whirler.*

Brassert modifications of the Brassert-Witting whirler, which is shown in Fig. 3, the lower portion *E* of the casing is larger in diameter than the upper portion *B* and is provided with a series of inwardly projecting baffle plates, *F*. The lower portion of the casing *E* is cone-shaped and constitutes the dust-receiving chamber. In the bottom of this chamber is a cone, *H*, whose purpose is to direct the dust toward the periphery of the dust outlet. Within the chamber *I* another cone, *J*, is located and this is provided with a series of baffles, which are arranged as shown in Fig. 4.

In another modification, a spiral, *L*, is provided in the casing for the purpose of directing the flow of the gas. The lower end of the receiving pipe is made barrel-shaped. The outer casing *M* in its lower portion *N* is supplied with the baffles *O*, which instead of being straight in the casing are bent inwardly therefrom, thus forming curved baffles *P* (Fig. 6). The section *N* of the casing is inclosed by an inner casing, *Q*, thus forming the annular chamber *R*, in which baffles *S* are placed to prevent whirling of the gas in this annular chamber.

The gas is introduced and discharged and the dust is separated in a manner to that mentioned in the description of the Brassert-Witting whirler.

#### *Dyblie Whirler.*

In the Dyblie whirler, as in most of these types, the separation is accomplished by the combined centrifugal force and the action of gravity. One

of the principal features in this particular whirler is the arrangement in the spiral separator of the entrance and exit openings in substantially the same horizontal plane, obviating the necessity of the gas changing its direction of flow at a sharp angle.

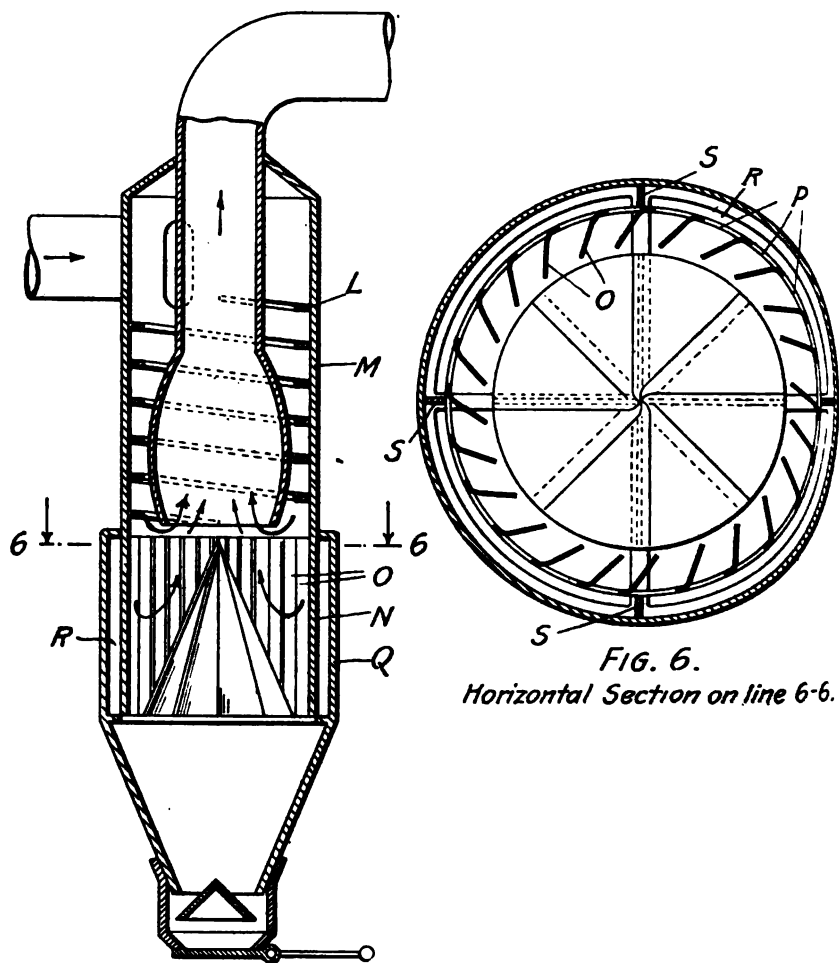


FIG. 5.

FIGS. 5 AND 6.—BRASSERT MODIFICATION OF BRASSERT-WITTING WHIRLER.

Described in general terms, this separator consists of a spiral conduit, the lower open edges of which connect with the dust-collecting chamber. The gas is introduced tangentially and follows a spiral course toward the central axis of the apparatus, the spiral conduit being increased in area before the gas enters the central chamber, prior to its exit from the apparatus.



The dust is separated from the gas by centrifugal force and gravity, and falls through the lower open edges of the spiral into the dust-collecting chamber. The central chamber is provided with a small opening at its lower end, and connects with the innermost spiral of the spiral conduit.

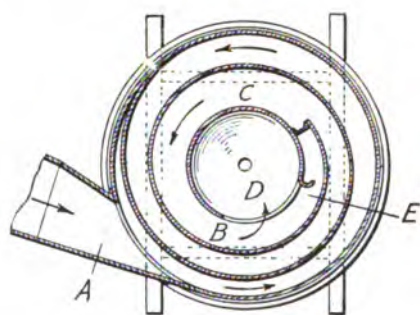
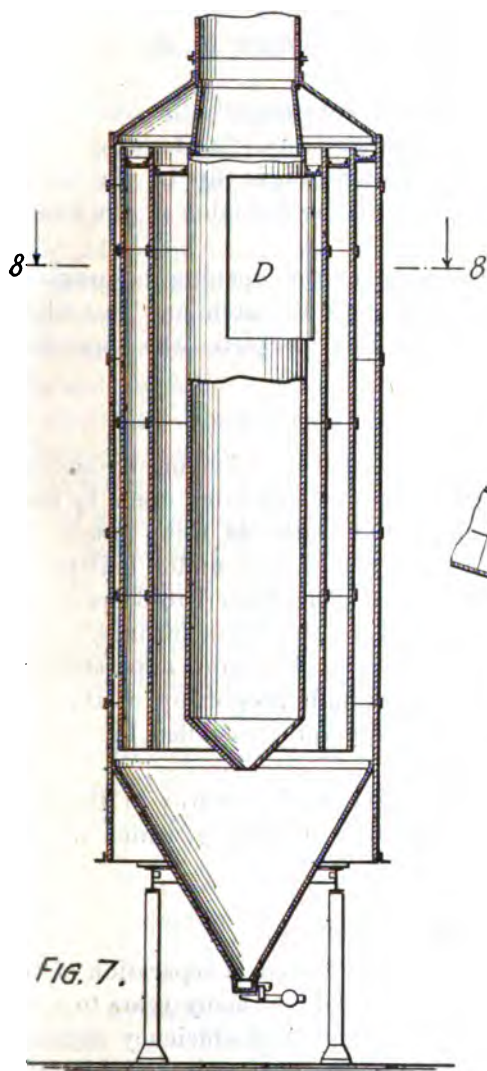


FIG. 8.  
Horizontal Section on line 8-8.

FIGS. 7 AND 8.—DYBLIE WHIRLER.

In the accompanying sketches, Fig. 7 is a vertical section through the Dyblie whirler and Fig. 8 is a horizontal section. The gas enters tangentially from the gas main through the opening *A* in the shell of

the casing; the gas impinges upon the first turn of the spiral *B* and follows the turns of the spiral. A separation of dust from the gas occurs through centrifugal force, the particles of greatest specific gravity being thrown outwardly and falling by gravity to the bottom of the casing.

At the point *C*, an increased area is provided between the spiral and the central chamber, which causes a decrease in the velocity of the gas, thus allowing a further separation.

The inlet *A* and the outlet *D* are in substantially the same horizontal plane, and this permits the separated material to drop out of the whirling gas and prevents its being caught up in the vortex, which happens when a sudden change in the direction of the flow of the gas occurs.

A deflector, *E*, located at one edge of the opening, is provided. This is in the shape of a hook, which acts to catch any dust which might be carried into the casing, and this completes the separating operation.

#### *Remarks on Efficiency of Dry Cleaning.*

It has been demonstrated in practice that dry cleaning by any one of the systems so far referred to, cannot be depended upon by itself to continuously clean the gas from blast furnaces using much fine ore, to the degree desired for use in stoves and under boilers, the amount of dust remaining in the gas ranging from 1 to 8 grains per cubic foot, depending on the working of the blast furnace. Such systems have a value, however, in removing, by simple apparatus and at practically no operating expense, a certain proportion of the dust and so decreasing the duty upon any apparatus installed for further cleaning.

The above remarks on dry cleaning refer in no way to the Halberger-Beth system, recently developed in Germany, which will be treated separately later on in this paper.

#### PRIMARY WET CLEANING.

For primary cleaning, in Europe in particular, a separation of the dust by the use of water has been preferred for many years to a dry separation, on account of the very much greater efficiency obtained in cleaning, and on account of the importance of reducing the water vapor contents of the gas to a minimum, thus allowing more efficient combustion. The cooling and washing of the gas are usually performed simultaneously, sufficient water being used to reduce the temperature of the outgoing gases to practically the temperature of

ing wash water. Experience has shown that cooling the manner, to allow condensation and separation of the water causes less attendant loss of heating efficiency than prevails in the vapor-laden gas.

### *Zschocke System.*

The washers have been used almost entirely in Germany for gas cleaning. These consist of cylindrical or square steel towers with a series of wooden grids or hurdles placed at suitable intervals within the apparatus. These hurdles are arranged in such a manner that the water, which is sprayed in at the top of the tower, is broken up into very fine streams, which drip down between the hurdles and meet the gas coming up, the gas being introduced at the bottom of the tower. The intimate contact so obtained wets the dust, which is carried with the water to the bottom. These towers are usually water-sealed and cone-shaped at the bottom. The latest type has a siphon arrangement; in either case, the tower is readily removed from the bottom of the apparatus.

The towers have been found sufficient to cool and clean the gas to the proper degree for use in hot-blast stoves, under boilers, and for similar purposes. A fan washer, into which water is introduced, is frequently used as an auxiliary to the Zschocke towers for gas cleaning, especially when the scrubbing capacity of the towers is small.

A gas separator, equipped with internal baffles, is usually located below the washer to allow separation of the entrained water.

The washers are used considerably in the United States, and several additional systems have also been developed here for the wet cleaning of dust; for instance, the Duquesne spray tower and the spray tower. The basic principle of these spray towers is the creation of a rain or spray by means of suitably sized nozzles, and the gas is cleaned and cooled in passing through the spray.

### *Duquesne Spray Tower.*

The Duquesne tower consists of a shell about 80 ft. high by 12 ft. in diameter. As shown in Fig. 9, the tower contains five sets of double screens being spaced 6 ft. 10 in. apart. Under the first set of screens are distributed seven nozzles, the feed water for which is controlled by a valve outside the tower. Under the fifth set of screens, seven spray nozzles, also controlled by a valve outside the tower, are located just above the range of the lower nozzles.

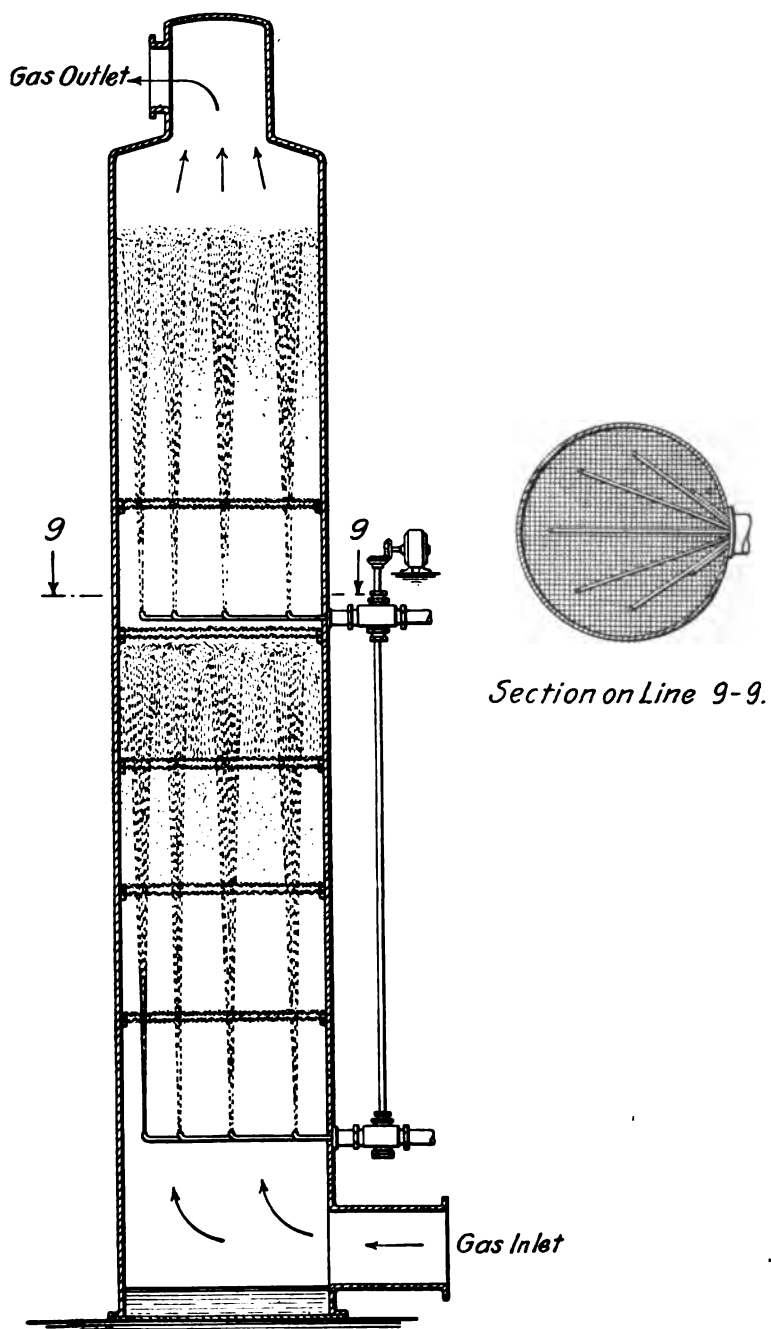


FIG. 9.—DUQUESNE SPRAY TOWER.

rolling valves have a revolving core which successively opens the openings to the different nozzles, thereby temporarily stopping the flow of water and creating an area of low pressure directly in front of the nozzle. When the core has passed, the flow of water rushes through this nozzle and sprays the gas which has reached this point. The core is revolved electrically, at the rate of about 15 rev. per min. and a 5-h.p. motor is ample to operate four valves, which are used for two towers.

The nozzles, which are placed above the nozzles, break up the water into fine drops, permitting intimate contact of the gas and the water. In the operation of these towers at Duquesne, the gas rises through the tower at the rate of 4 ft. per second, and the water at the rate of 1 ft. per second with a head of 35 lb. main pressure. The gas is cleaned very effectively, the temperature of the outgoing gas being only from 5° to 6° F. above the temperature of the incoming gas. The moisture content averages only about 0.5 grain per cubic foot above the saturation point at the temperature of the out-

### *Bian Gas Washer.*

The Bian gas washer, as shown in Figs. 10 and 11, consists of a horizontal steel cylinder through which the gas passes from one end to the other. Inside the cylinder, there slowly revolves a shaft carrying a number of vertical disks consisting of wire netting of fine mesh. The diameter of these disks is very slightly less than the diameter of the cylinder, and this arrangement necessitates the gas passing through the openings in the screens as it travels through the washer. The screens, to the extent of nearly half their diameter, are immersed in a trough upon which the open bottom of the cylinder rests, and as the shaft revolves, the part of the screens which has been immersed rises from the water with the meshes carrying thin films of water, thus allowing thorough contact of the gas as it passes through the perforations.

### FINAL WET CLEANING.

(These systems can also be applied to primary cleaning.) The amount of cleaning accomplished in Zschocke and similar washers in the Bian washer, while satisfactory for stoves and engines, was found to be not sufficient when the gas was destined for use in gas engines, and the systems of Theisen and Schiele were devised for this purpose.

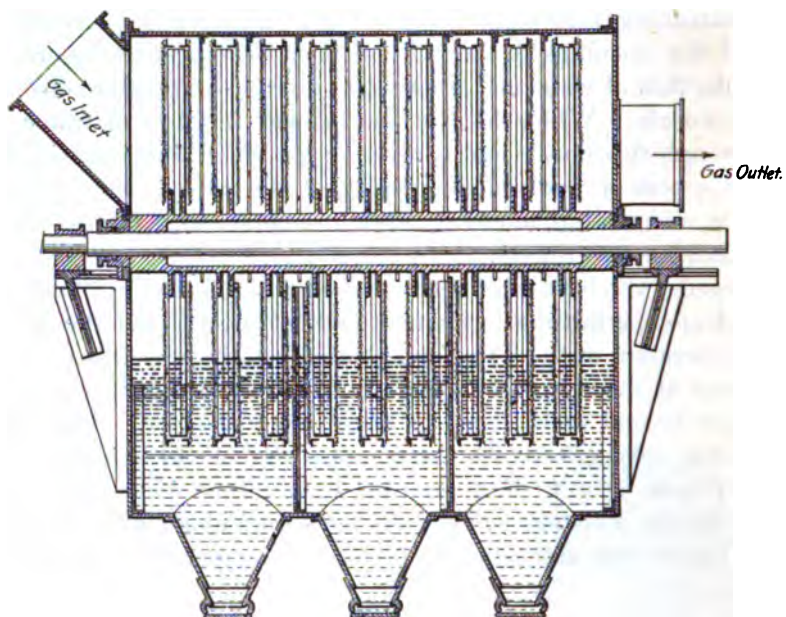


Fig. 10.

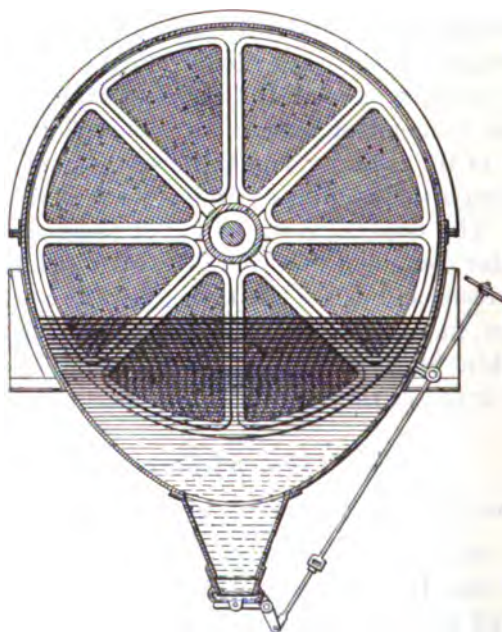


Fig. 11.

FIGS. 10 AND 11.—BIAN GAS WASHER.

*Theisen Gas Washer.*

Theisen washer, as shown in Figs. 12 and 13, consists of a drum with a special wire netting, within which revolves at a slow speed, a drum carrying numerous fan blades set at oblique angles to the axis of rotation, these blades or vanes being so fitted

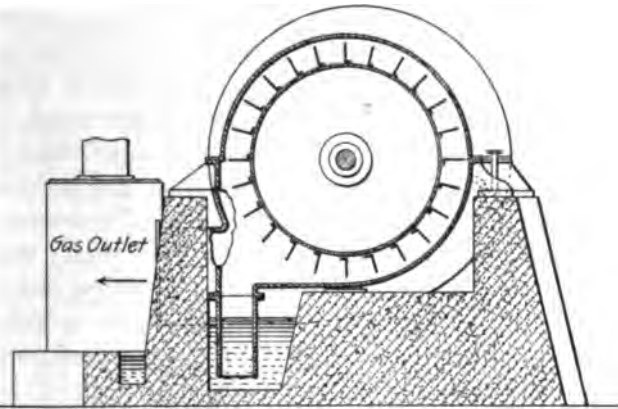


Fig. 12.

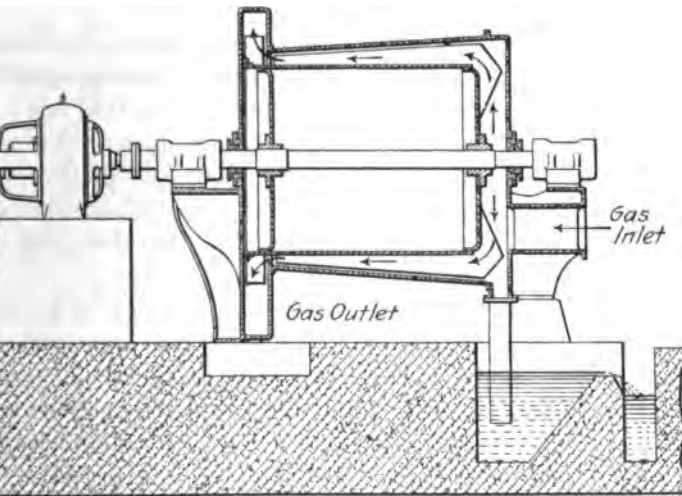


Fig. 13.

FIGS. 12 AND 13.—THEISEN GAS WASHER.

form a continuous spiral curve. This allows the gas to be admitted at one end of the casing and expelled at the other end. The gas is admitted at the side of the casing and is converted into a spiral by the revolutions of the blades, and the spiral arrange-

ment of these blades causes the spray to flow in the opposite direction to the gas, which passes through this spray, being simultaneously cleaned and cooled. The dirty water leaves the apparatus by a water seal at the bottom.

The Theisen and Schiele systems of final wet cleaning have for years given very satisfactory results, but are now being gradually superseded by systems requiring less capital expenditure and less operating expense. Most of these systems can be used for primary cleaning as well as for final cleaning, by installing in two stages. The most important of the wet cleaning systems which perform as efficient cleaning with the consumption of much less power and water than the Theisen and Schiele systems are the disintegrator system of Theisen, the disintegrator system of Schwarz-Bayer, the Fowler & Medley rotary washer, and the Feld rotary washer, while the Halberger-Beth dry cleaning system of filtration through canvas is remarkably efficient in cleaning and is cheap to operate. Following is a detailed description of each of the systems mentioned, together with several other modern systems:

#### *Theisen Disintegrator Gas Washer.*

There are two styles of Theisen disintegrator gas washers. One style consists of a casing in which the gas enters by two apertures at the base of the apparatus and is washed by a spray of water in a perforated drum or cage equipped with vanes, the drum revolving within a stationary drum, the gas being drawn through the apparatus by a fan mounted on the same shaft and discharged with the necessary pressure to carry it to the point of consumption. The second style also has the fan mounted on the shaft, but the fan is inclosed within the disintegrator.

The Theisen disintegrator consists of a series of rotary and stationary perforated drums or cages arranged concentrically within one another, as shown in Fig. 14. The stationary drums consist of round bars and the revolving ones of angle bars. The hot raw gas enters the apparatus at the bottom, meets the effluent water and undergoes a preliminary cooling and cleaning in the lower part of the machine. The gas is drawn in counter-current through the series of rotary and stationary drums by means of a fan. The water is converted into a fine spray by the centrifugal action of the rotating drums, and the gas, passing through this spray, is cleaned. The fan is located in the same casing and on the same shaft as the rotary disintegrating drums, the shaft being direct motor driven. Fresh water is introduced into the innermost rotating drums in the form of a finely divided spray.



ing and cleaning of the gas and production of the pressure to conduct the clean gas to its point of consumption are all in one apparatus and with one motor. It is stated that

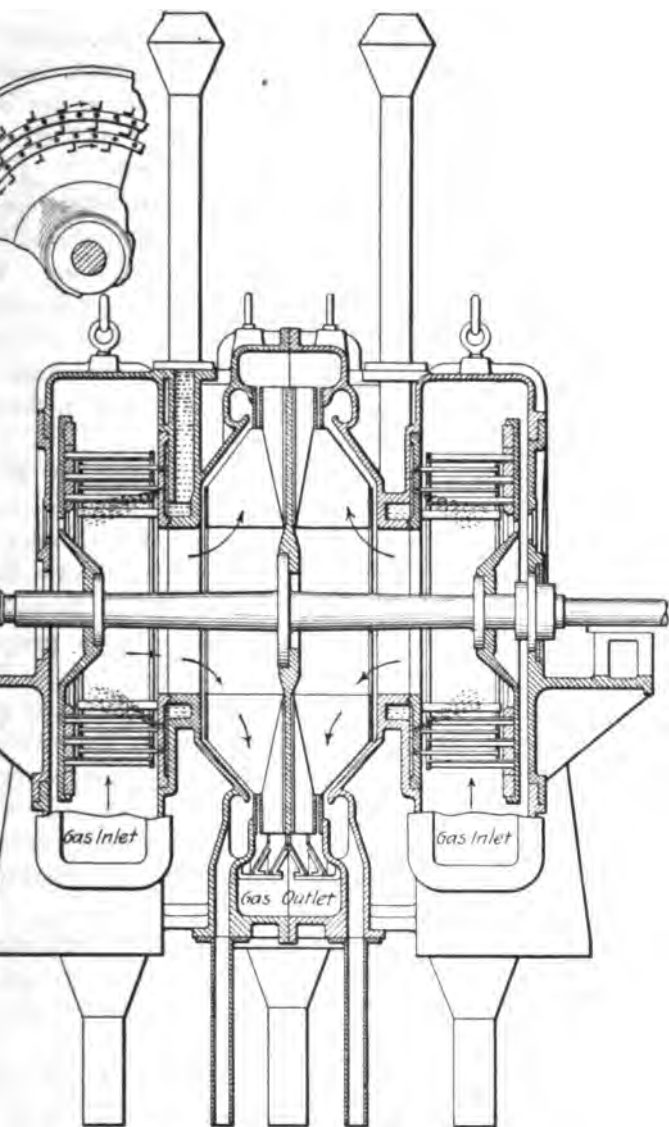


FIG. 14.—THEISEN DISINTEGRATOR GAS WASHER.

Disintegrator is an improvement over the former Theisen apparatus, requiring much less power and water, and performing the cleaning of the gas without preliminary towers.

*Schwarz-Bayer Disintegrator Gas Washer.*

The Schwarz-Bayer system of gas cleaning makes use of the disintegrator principle, and its general arrangement is simple. The complete set of gas-cleaning apparatus consists of a disintegrator in connection with a saturating chamber in the form of a hood; then a fan placed immediately behind the disintegrator, and finally a water separator. In case both primary and final cleaning are desired, two such sets of apparatus are used, the second of which further cleans the gas which has been primarily cleaned in the first.

The disintegrator, as shown in Figs. 15 and 16, consists substantially of two sets of steel pins, cold-riveted to two steel disks, which disks are set side by side and revolve in opposite directions. The pins of one revolving disk, which interlace with the pins of the other revolving disk, form with the water, through the effect of rotation and dripping, a fine spray or mist, which allows a thorough mixture of the water with the gas traveling among and between the pins before leaving the apparatus.

The gases from the blast furnace pass from the raw gas mains directly into the disintegrators without previously passing through Zschocke towers or similar preliminary washer or cooler. The gas enters through the top of the hood and passes toward the center of the disintegrator, while water is being introduced through the sides to the center. The hood acts to some extent as a pre-cleaner and cooler, as some of the spray from the disintegrators is thrown into the hood and there comes in contact with the hot gas and rapidly evaporates, simultaneously cooling the gas. By the revolution of the disintegrator the water is projected toward the periphery of the apparatus and is broken up into a fine spray; the gas mixes thoroughly with this water and is cooled, and most of the dust contained in the gas is precipitated. The gases pass through the disintegrator in a current counter to that of the water.

The application of the counter-current principle enables the gas to encounter cleaner and colder water in its passage through the disintegrator; hence it is better cleaned, and its temperature is reduced more nearly to the temperature of the entering cooling water. This principle has the effect of materially reducing the amount of water and power consumed. Each disk is direct driven by an individual motor and the speed is determined by the degree of cleanliness desired in the gas. The gas is drawn through the disintegrator by means of a fan located immediately behind the disintegrator apparatus, and passes from the fan to a water separator.

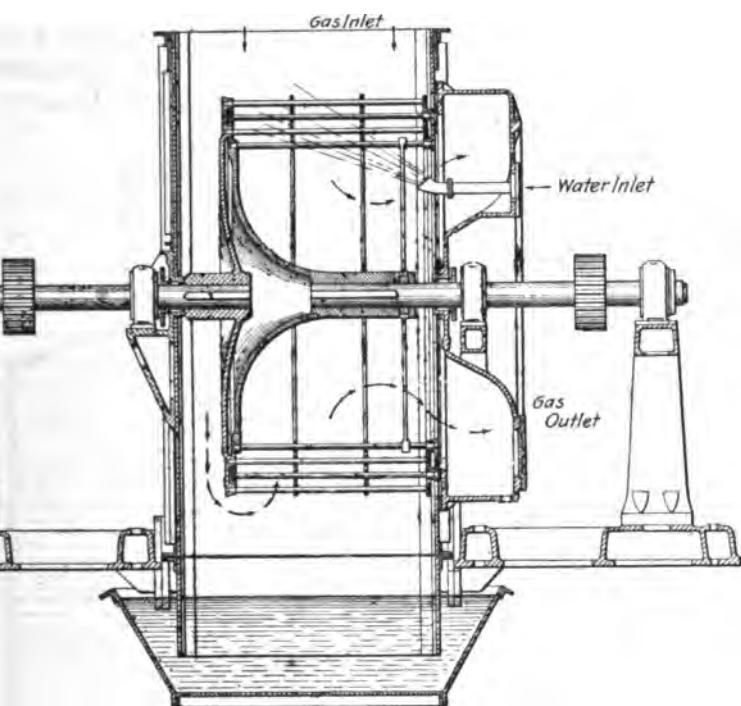


Fig. 15.

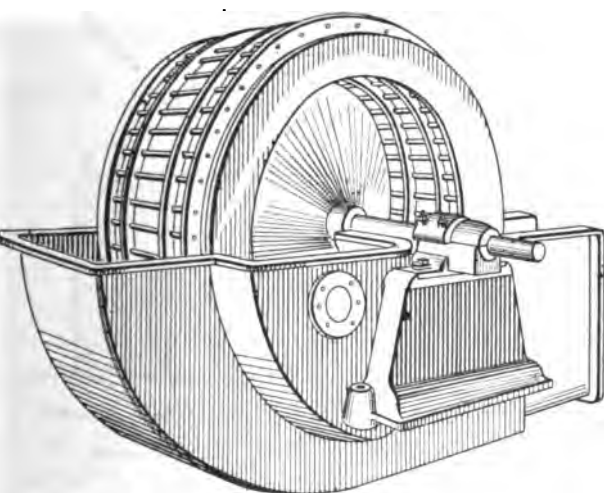


Fig. 16.

FIGS. 15 AND 16.—SCHWARZ-BAYER DISINTEGRATOR GAS WASHER.

The use of pins in this apparatus as a disintegrating medium allows the passage of the gas with very little resistance, and a consequent saving in power. There is also very little possibility of the dust settling on the pins and clogging up the apparatus.

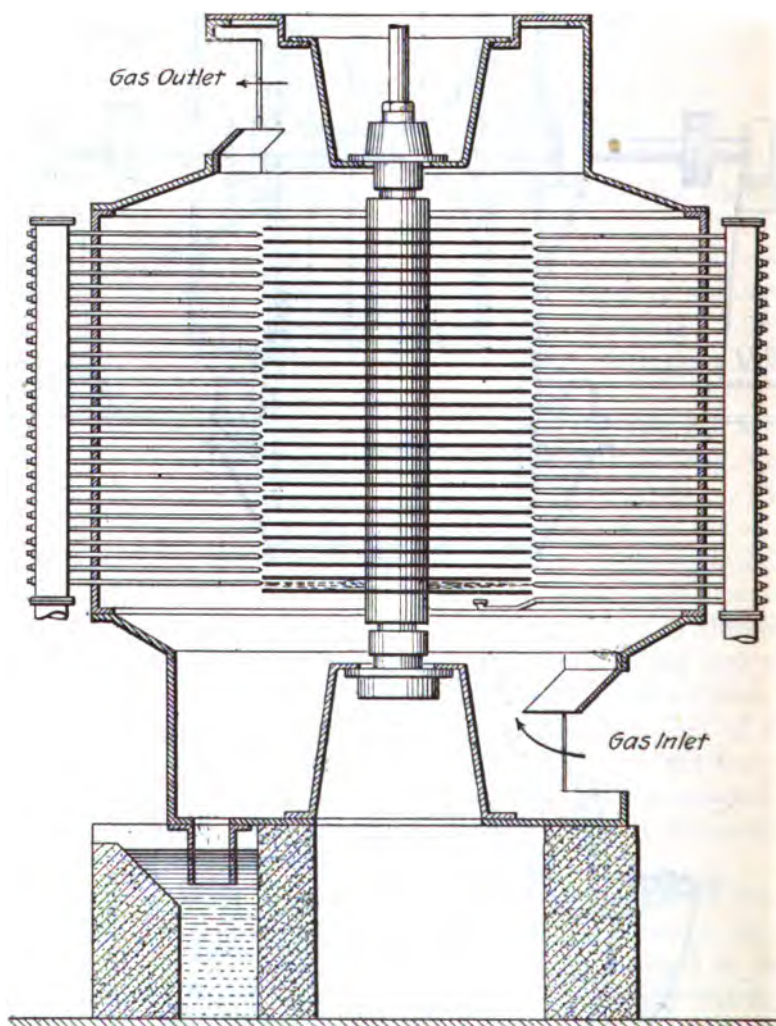


FIG. 17.—FOWLER & MEDLEY VERTICAL GAS WASHER.

*Fowler & Medley Vertical Gas Washer.*

This apparatus, as shown in Fig. 17, consists of a circular cast-iron casing containing a revolving shaft running vertically through the middle. On this shaft are fixed a number of disks, made either of steel or of cast iron, depending upon whether the water used is alka-

line or acid. Each disk is equipped with a collar separating it from the adjoining disks, and each collar is punched or drilled with six holes, through which six bolts pass vertically, thus holding all the disks in place. The shaft is direct driven with a vertical-spindle motor. Two fixed water sprays are provided for each disk, diametrically opposite each other, one on each side of the washer and projecting between each pair of disks. The jets of water, which are introduced through nozzles having about  $\frac{1}{4}$ -in. openings, enter with sufficient pressure to strike the collar between the disks, and, as the disks revolve, the water is thrown against the top and bottom of these disks and then against the outside wall of the casing, creating a fine spray or mist in the space between the outer edge of the disk and the wall of the casing, through which space the gas passes. The gas enters the washer at the bottom, passes through this spray or mist, and leaves clean at the top.

This washer can be used for either primary cleaning or final cleaning, or both; in case final cleaning is desired, two washers would be used in series, the first apparatus to clean the gas sufficiently for primary purposes and the second apparatus to finish the cleaning of the gas for gas-engine use.

#### *Feld Gas Washer.*

The Feld washer, as shown in Fig. 18, consists of a series of superimposed sections, the bottom of each section being provided with ports for the passage of gas. The gas enters the bottom of the washer and passes from chamber to chamber to the top, whence it is led away. Each section or chamber is provided with a series of cones perforated at the top and mounted upon a cast-iron spider, which is carried on a vertical shaft. The shaft is suspended at the top in a specially designed anti-friction bearing, arranged so as to reduce the power required for operation to a minimum. The water is admitted into the top of the washer and overflows from section to section through the gas ports, the dirty water saturated with dust leaving the bottom of the washer.

When the shaft revolves, the cones do likewise, and the water is raised by centrifugal force along the inner sides of the cones and is atomized at the upper edge. This upper edge of each cone is a little higher than the next outer one, thereby forming a certain number of horizontal sprays of water, depending on the number of cones. The upper portion of the outer cone, which is somewhat higher than the inner one, is perforated. The inner cones supply water to the perforated surface of the outer one. This results in the formation of a

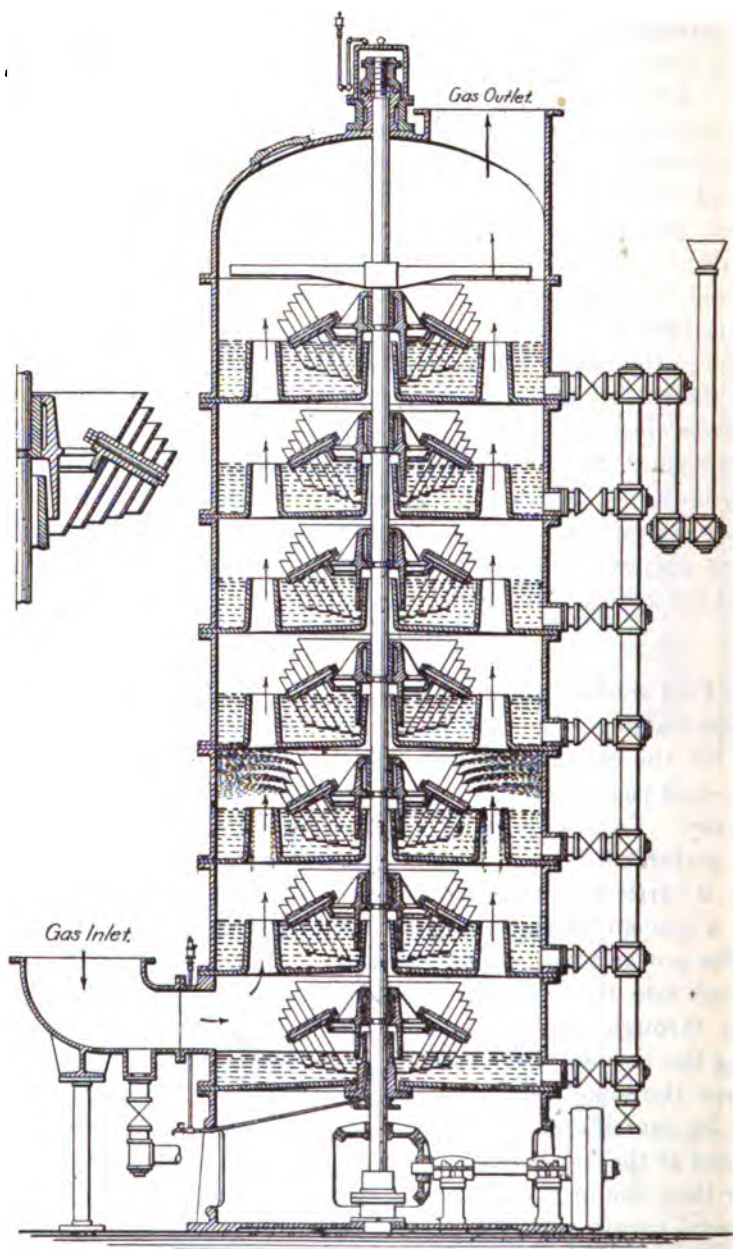


FIG. 18.—FELD GAS WASHER.

cascades composed of very small drops of water, through gas must pass *en route* through the apparatus. Washing is accomplished mostly in the lower sections, while the upper sections perform primarily the function of cooling the gas. For primary washing, the Feld washer is constructed with seven vertical sections, the lower three being the washing chambers, the middle one being a separating chamber and the upper three being cooling chambers. For final washing, in the case of the gas required for gas-engine purposes, the gas after being primarily washed is passed through an additional washer of the same general type.

### *Reco Centrifugal Gas Washer.*

This washer is constructed by the Roessing-Ernst Co., of Philadelphia, Pa., and is designed to cool, clean and, if necessary, dry the gas in one apparatus. This washer consists substantially of a vertical casing, a tube whose lower end is provided with serrations extending to within a few inches of a water seal, a revolving inverted cup, a sleeve casing attached to the inverted cup. The outer casing, the cup, the tube, and the sleeve casing are provided with radial vanes. The apparatus is belt-driven. The spindle of the cup, which the driving pulley is fastened is hollow, and the rotor is taken up by the shaft inside of this sleeve, held in place by a bearing which is backed by a rubber buffer in order to prevent any irregularity during rotation.

As shown in Fig. 19, the hot gas enters the apparatus at the point A, passes over the water, a certain amount of which the gas takes up in the process of solution, and then passes into the tube B through the serrations at its base. During its passage through this tube the gas and water are subjected to a thorough beating and mixing by the action of the vanes C of the revolving sleeve casing D, fastened to the inverted cup E. The gas passes into this inverted cup which is rotated by the driving sleeve F and the pulley G, and is thrown downward, around and under the lower edge of the cup and upward between the cup and the outer casing H. The outer casing, the revolving cup is provided with concentric shelves K. The outer casing H is provided with downwardly inclined shelves which receive the washing water from the water-sealed stuffing box and pass it through a series of water pipes L. The water, falling on the rotating shelves of the cup, is thrown by centrifugal force against the inner walls of the casing and thence flows downwardly on the inclined shelves, dripping on to the next rotating shelf, and in this way the gas, while subjected to a thorough whirling

and beating action, has to pass upward through several films of finely divided water or spray while the water passes downward, carrying with it the separated impurities.

The apparatus operates on the counter-current principle, the cleanest gas passing from the apparatus meeting the cleanest water entering the apparatus.

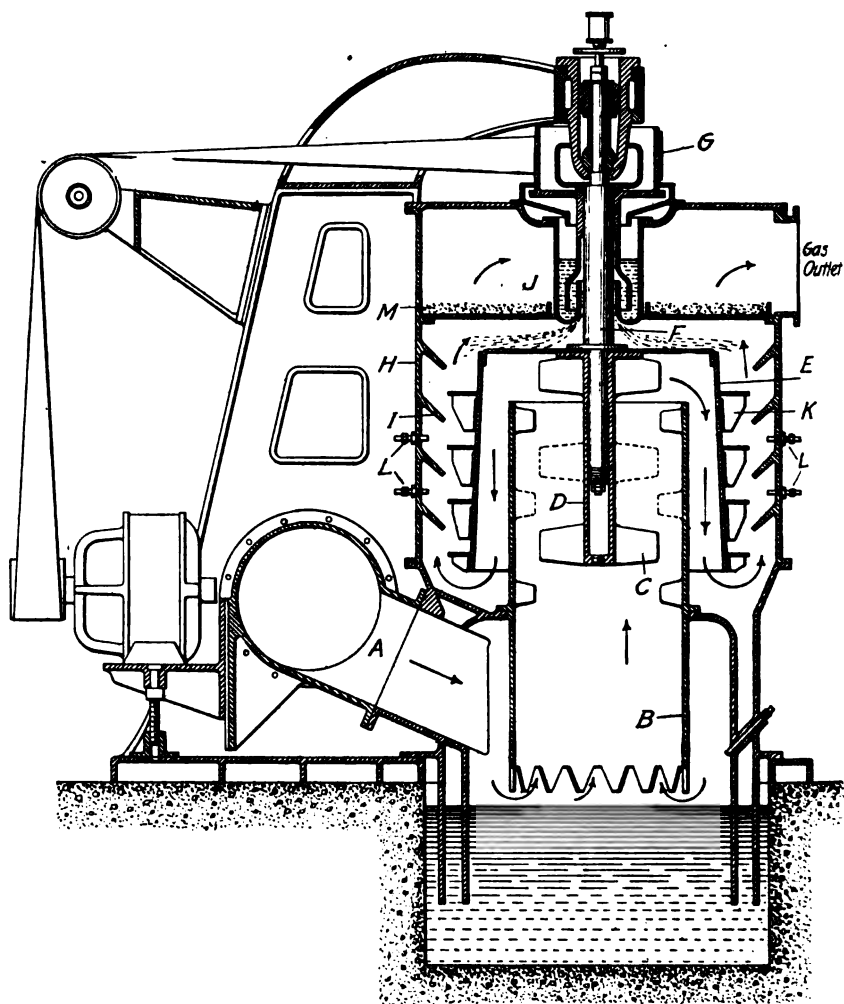


FIG. 19.—RECO CENTRIFUGAL GAS WASHER.

The upper part of the casing is provided with a rack which, it is stated, can be packed with suitable drying material in case it is desired to dry the gas before leaving the apparatus.



*Sepulchre Gas Washer.*

em is designed as a final washer to further clean primarily  
d cooled gas to the degree necessary for use in gas engines.  
ole of this system consists in creating in a vertical tower a  
pray or mist of water by means of an injector of the Kört-  
n which water under pressure is atomized by means of  
blast-furnace gas, the spray being produced by the ex-  
the compressed gas. An intimate mixture of the spray so

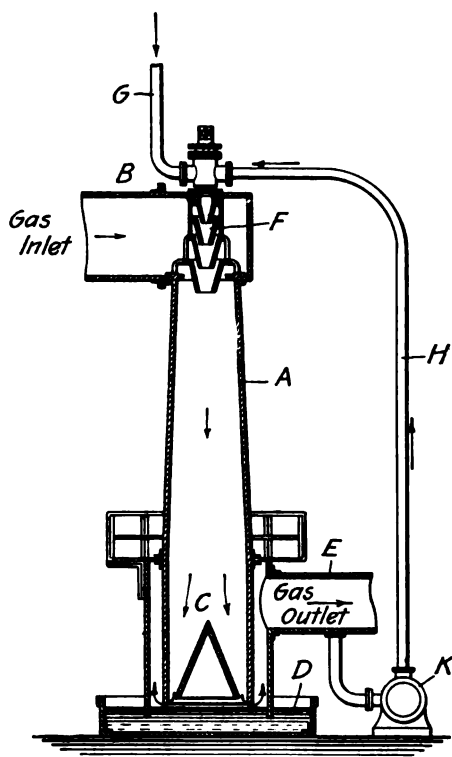


FIG. 20.—SEPULCHRE GAS WASHER.

ch the dirty gas entering the apparatus, is obtained by the  
nt of the apparatus.

tor is provided in connection with this apparatus, which  
ostantially of a cone arranged in the lower part of the  
ch a way as to leave between the base of the cone and the  
e tower a very narrow passage, through which the gases  
ver the surface of a water seal, where the dust and water  
deposited.

In the accompanying drawing, Fig. 20, *A* is the vertical tower, the lower end of which terminates a short distance above the surface of the water seal *D*. Within the lower end of the tower is arranged a conical deflector, *C*, and near the top of the tower is the gas inlet, *B*. The lower section of the tower *A* is surrounded by a casing which is open at the bottom and extends beneath the surface of the water in the seal. A gas outlet, *E*, is provided in connection with the outer casing. The Körting injector is located at *F* and the feed water for same is supplied through the pipe *G*. The pressure is supplied by withdrawing a portion of the purified gas from the outlet pipe *E* and forcing this by the compressor *K* through the pipe *H* into the injector simultaneously with a stream of water.

#### FINAL DRY CLEANING.

(Some of these systems can also be applied to primary cleaning.)

##### *Halberger-Beth Gas-Cleaning System..*

The principle of the Halberger-Beth system, shown in Fig. 21, is based primarily on filtering the gas through canvas bags. The gas coming from the blast furnace passes through the usual dust catchers and gas mains to a cooling tower, where the temperature of the gas is reduced to about 175° F. The cooling tower is arranged so that the necessary amount of cooling can be accomplished either by air or by direct contact with water, depending on the temperature of the gas entering the cooler, which temperature is naturally variable, in accordance with blast-furnace conditions.

From the cooler, the raw gas, by means of the suction of a fan placed beyond the filters, or without a fan when the pressure of the gas issuing from the furnace is sufficient, passes into and through the canvas filtering bags, depositing its impurities on the surface of the bags. These canvas filters are contained in a series of double compartments, each usually holding 12 canvas bags in rows of three by four. Each bag is about 8 in. in diameter by 9 ft. 9 in. long, and is equipped with a ring at each 18 in. of its length to prevent entire collapse of the bag when cleaning. The bags are fastened into a stationary header at the bottom, this bottom end being open, while the top is closed by a steel plate. Each bag is connected with a shaking mechanism located outside and above the filter compartment, and at regular intervals, usually about every 4 min., these bags are automatically shaken, a compartment at a time, for a period of from 15 to 20 sec. By means of a butterfly valve, the uncleaned gas is shut off from the compartment while the shaking is in progress, and

gas, superheated to the proper temperature of about  $175^{\circ}\text{F.}$ , under pressure into the compartment. This causes a partial release of the canvas bags, which, in conjunction with the simultaneous shaking, allows the dust to fall from the canvas. The separated dust falls into a hopper beneath the sacks, whence it is transported by means of a spiral conveyor to a bin, from which it is loaded. At the end of the cleaning period the butterfly valve automatically returns to its original position and filtering commences.

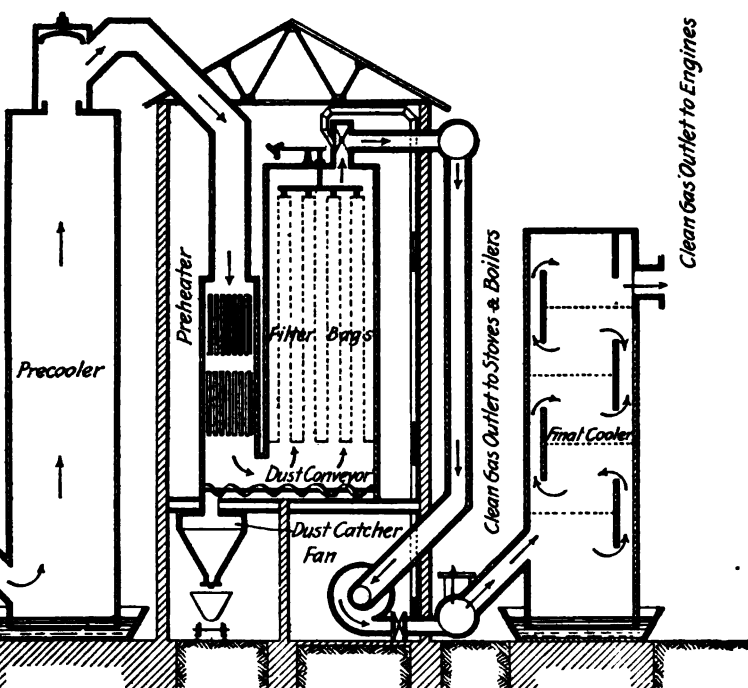


FIG. 21.—HALBERGER-BETH GAS-CLEANING SYSTEM.

It is necessary to keep the temperature of the gas at about  $175^{\circ}\text{F.}$  if much higher than this there is danger of scorching the filter bags. If lower the water vapor in the gas is deposited on the filter bags and prevents proper filtration. In case the gas becomes cooled below  $175^{\circ}\text{F.}$  in the cooling tower, it is superheated by means of a coil through which waste heat from the hot-blast stoves to about this temperature before entering the filtering bags. After leaving the canvas filter bags the gas requires no further cleaning for gas engines and is sent directly to the proper temperature in cooling towers of various

The degree of cleanliness of the gas is indicated by the clearness of the effluent water from these towers and no settling basins are required. Consequently, this water can be used over and over again, which is a material item in districts where water is scarce. A further advantage lies in the non-pollution of streams, the laws relating to which are very strict in certain districts.

This system utilizes the basic principle employed in the "bag house" system, which has been used for the last 20 years in connection with recovering zinc dust from the gas issuing from zinc oxide furnaces and collecting dust from lead smelters.

#### *Smith-Bagley Gas-Cleaning System.*

A modification of the Halberger-Beth system has been recently devised in England, but has not yet been demonstrated on a practical scale. This consists substantially in replacing the stationary canvas bags used in the Halberger-Beth process by traveling belts composed of canvas or similar textile material.

In this process, it is proposed to cool the gases, after leaving the dust catchers, to the prescribed temperature, by means of a tubular cooler so arranged that fluctuations in temperature can be automatically equalized by an electrical device controlling butterfly valves in the base of certain sections of the gas tubes within the cooler, which will increase or decrease the amount of cooling surface. When duplicate coolers are installed, the electrical governor automatically connects the second cooler with the first in case of any rise in temperature.

After leaving the coolers, the gas enters an apparatus containing a series of belts made of a special textile fabric. These intersect the casing of the apparatus at right angles to the direction of the flow of the gas. The area of these belts is determined by the desired speed or flow of the gas and their texture and composition. By using special fabric for the belts, a certain degree of flexibility is attained by stretching the fabric or releasing the tension in any desired section. This is accomplished by rollers placed before the main operating rolls in the direction of the movement of the belts. The gas passes through the belts and the dust particles are deposited on the surfaces nearest the incoming gases. The belts move continuously and enter and leave the casing of the apparatus through gas-tight rolls suitably covered. The belt fabric and the two roll surfaces make a gas-tight joint.

On leaving the casing, the dust-laden belt enters the magnetic field of a separator, which withdraws any metallic and magnetic dust par-

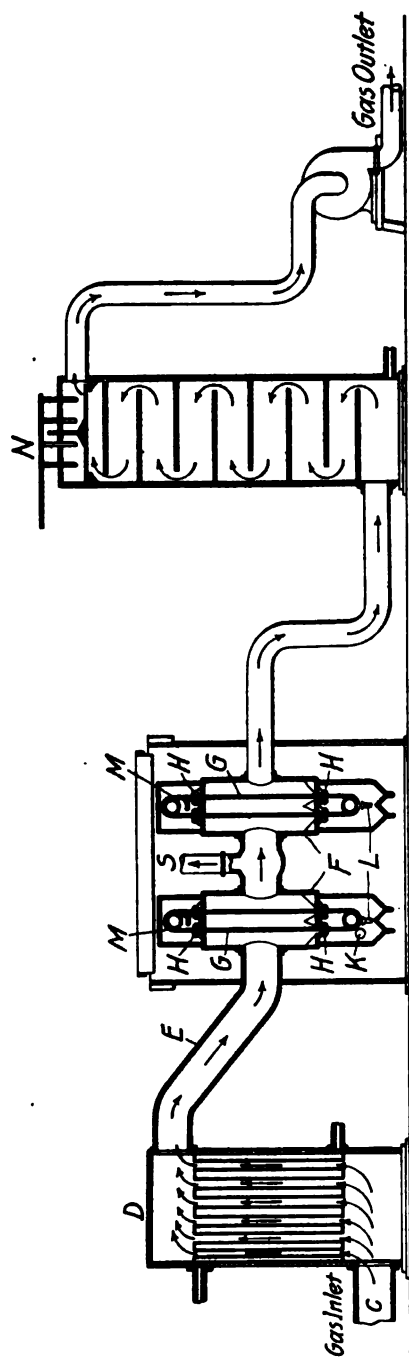


FIG. 22.—SMITH-BAGLEY GAS-CLEANING SYSTEM.

ticles and removes these to a separate bin. The belt then moves forward to vacuum collectors, which remove the dust. Several of these vacuum collectors may be placed in series to operate on the belt so that when the belt re-enters the casing it is thoroughly clean and free from dust. It is then in condition to again be used for removing dust.

The back pressure exerted by the belts can be governed within certain limits by their speed. The bottom surfaces of the casing of

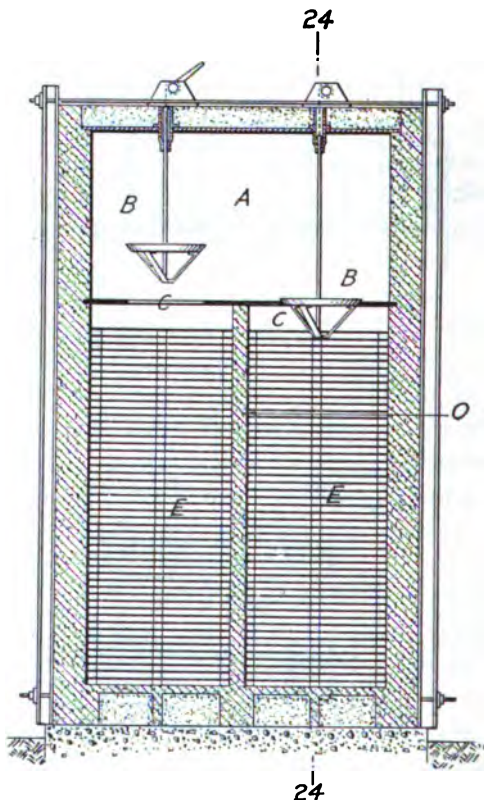


FIG. 23.—HOWARD DUST SEPARATOR. SECTION ON LINE 23-23 OF FIG. 24.

the apparatus are inclined to prevent any dust from accumulating, or pockets can be provided for a similar purpose.

After leaving this apparatus, the gas is cooled down to the desired temperature for use in gas engines by direct coolers.

As shown in the accompanying drawing, Fig. 22, the dirty gases from the dust catcher enter the tubular cooler *D* through the gas main *C* and pass by the gas main *E* to the dry cleaners *F*. The canvas filtering belts are indicated by *G* and the gas-tight rolls by *H*.

es the magnetic separator, *L* the vacuum collectors, *M* the  
e, *N* the final cooler, and *S* an outlet to stoves and boilers  
-cleaned gas.

ore stated, this process has not, to the writer's knowledge,  
d out on a practical scale, but presents probabilities of

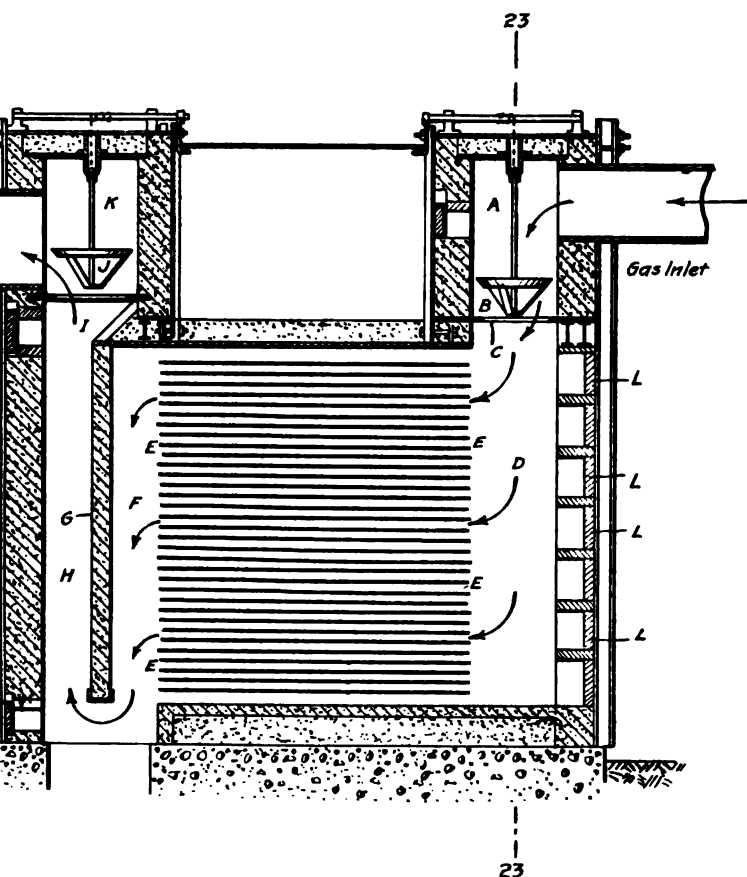


FIG. 24.—HOWARD DUST SEPARATOR. SECTION ON LINE 24-24  
OF FIG. 23.

### *Howard Dust Separator.*

apparatus which up to this time has not been applied to the  
removal of dust from blast-furnace gases, but which indicates fairly  
possibilities in this direction, is the Howard dust separator.  
This apparatus is used extensively in chemical manufacturing indus-  
tries for separating fine dust from such gases as those produced from  
pyrites fines in the manufacture of sulphuric acid.

The principle of this process depends upon the deposition of dust on a series of steel plates or shelves confined in a chamber of either brick or steel. These steel plates are usually No. 10 gauge sheets and are placed horizontally one above another about 2.5 in. apart. The gas enters the chamber containing these plates, the chamber being arranged in such a way that the gas is evenly distributed throughout the vertical height of the chamber by means of a baffle wall. The gas to be cleaned must pass over and between these shelves before leaving the chamber, and during its passage the dust is deposited upon the shelves, the deposition being due to the velocity of the gas being checked in passing between the steel plates by the large area of cross-section. As these plates are only 2.5 in. apart, the dust particles need to fall only this distance before finding a surface upon which to rest.

The dust first builds up at the entrance end of the shelves, reducing the space through which the gas flows, and gradually similarly builds up for the length of the shelves. Care must be taken to remove the accumulated dust before too much has gathered, as otherwise inefficient cleaning results. Cleaning holes with covers are provided to allow removal of the accumulated dust, and this is accomplished by means of a flat steel scraper, which is pushed by hand between the plates, thus driving the dust out ahead of the scraper.

In case a steel chamber is installed, as would be the case if this system were applied to blast-furnace gas, a special design has been made which allows ready access to the shelves by means of a sliding section.

In the accompanying Figs. 23 and 24, *A* is a brick entrance header or flue which the gas enters from the furnaces. *B* is a cast-iron damper capable of being closed or opened by a chain and pulley operated outside. *C* is a cast-iron plate with a damper opening over which the damper *B* closes. *D* is a vestibule which gives the gas free entrance to all the plates or shelves. *E* indicates horizontal steel plates placed 2.5 in. apart. *F* is an open space which permits free exit of gases from between all the plates. *G* is a baffle wall placed to equalize the flow of gas between all the plates. *H* is the exit vestibule. *I*, *J*, and *K* indicate the damper opening, damper, and discharge header. *L* indicates the cleaning holes with covers. The course of the gas is indicated by the arrow lines.

Fig. 23 shows a two-compartment separator, in which the dampers provided for each compartment allow one compartment to be cleaned while the other is in operation, *O* representing the division wall.



## SEPARATION OF DUST BY ELECTRICAL PRECIPITATION.

er method which possibly may be applied to the separation from blast-furnace gas is the electrical precipitation of sus-articles. This system has not so far been applied to any great the purification of blast-furnace gas, but is claimed to have essful in other directions in removing suspended matter from from air. An example of this is the separation of dust in plants. In this system, the dust is deposited upon rods or etrically charged by high tension direct current, which is ntly stopped to allow the collected dust to fall from the rods or wires into a hopper below.

## THE KAPNOGRAPH.

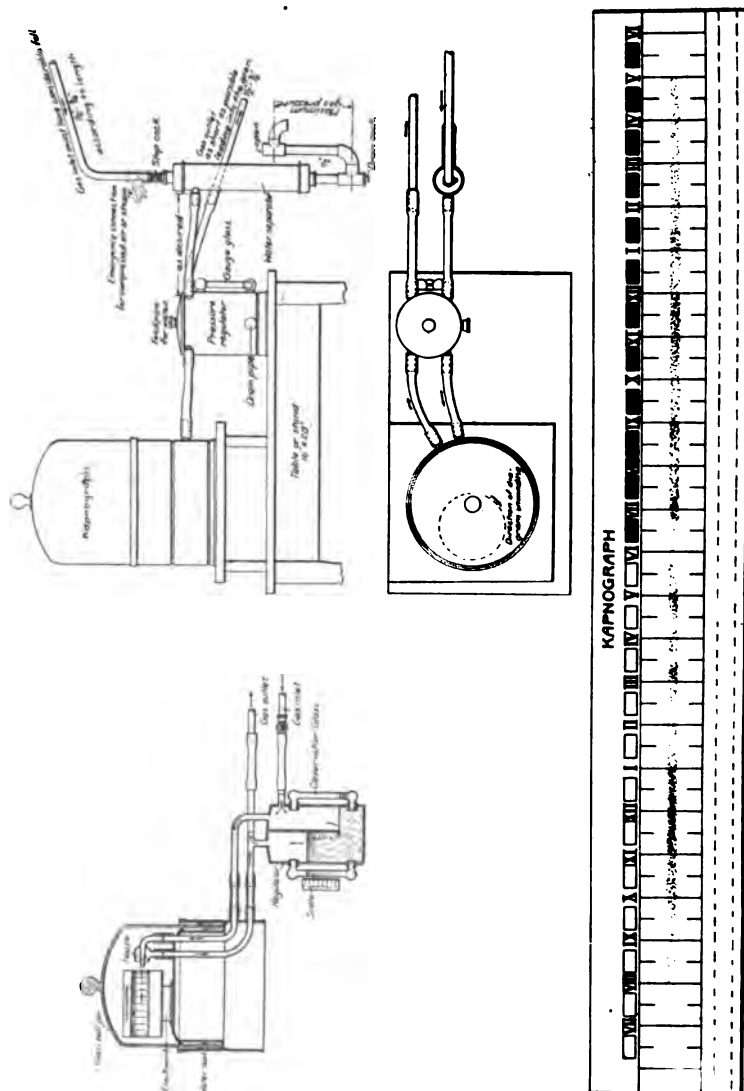
strument, shown in Fig. 25, continuously indicates the rela-ee of cleanliness of the blast-furnace gas going to the gas and is extensively used in European gas-engine stations. the cleaned gas main passes through this apparatus and upon a continuous recording chart, upon which the dust in deposited. The variations in the amount of dust in the dicated by lighter or darker shades on the recording paper, g on the amount of dust deposited. The flow of gas to the nt is maintained either by the natural pressure of the gas, s is not sufficient, by an aspirator behind the outlet pipe. d of the gas to the nozzle is kept constant by means of a , as shown in sketch, the excess gas over the required scaping into the outlet pipe by passing under a partition gh a seal of water.

## METHODS OF DETERMINING THE AMOUNT OF DUST IN BLAST-FURNACE GAS.

od employed with good results in Europe for determining nt of dust in the gas consists in drawing a definite quantity last-furnace gas to be tested through a filter, which is in a dry condition before and after the test. The apparatus nining the amount of dust consists of a glass tube drawn e end and fitted at the other with a ground-glass cover, also drawn out to a thin tube. This cover facilitates the f the filtering material in the tube, and during the test the astened to the tube by means of wire. Before the test, the e, filled with suitable filtering material, is placed in a drying and heated at a temperature of  $105^{\circ}\text{C}$ . until its weight is

constant, which usually requires from one to two hours. The drying furnace is arranged so that several tubes can be dried simultaneously.

During the drying process air is drawn through the tubes after having previously been thoroughly dried by passing through bottles



*Specimen of strip indicating one day's run at a European Gas Engine Plant.*

**FIG. 25.—THE KAPNOGRAPH.**

containing calcium chloride and concentrated sulphuric acid. During the drying process the tubes are weighed until no further increase in weight is observed.

In making the test, the weighed tube containing its filtering ma-

is inserted into the gas main, a rubber stopper keeping the tube tight. The upper end of the tube is connected with a gas meter which in turn is connected with a barrel filled with water. Water is allowed to flow out of the barrel and in so doing creates the necessary suction to draw the gas through the filtering tube and through the gas meter. When the necessary amount of gas has been drawn the tube is again dried and weighed. The increase in weight indicates the amount of dust in the quantity of gas tested.

*Dust, Moisture, and Volume Determinator for Blast-Furnace and other Gases.*

This apparatus has been devised in order to accurately determine the amount of dust and moisture contained in blast-furnace gas, as well as the volume of the gas, and is used with considerable success. Referring to the accompanying drawing, Fig. 26, *A* is a gas main carrying the gas to be tested. *B* is an aperture in the small pipe through which samples of the gas are drawn. *C* is a filtering medium through which the solid constituents of the gas are deposited. *D* is a tube leading to the exterior of the gas main through which the gas is conducted. *E* represents a flexible connection to a condenser, *F*. *G* represents a receptacle for some chemical, such as calcium chloride, which can be used for the purpose of taking the moisture contained in the sample. *H* is a conduit from this moisture-receiving receptacle to the rotary air pump, *I*, or through which the gas passes *J* to the three-way valve *K* and thence to the gas meter where the volume of the sample is determined, together with its temperature and pressure; these latter by means of the thermometer and the U-tube *N*, respectively. An electric motor, *O*, is used to drive the pump *I* through the variable-speed drive *P*.

An indication of the velocity of gas or gases in conduit *A* is transmitted through aperture *Q* in the sample pipe and conduit *R* to horizontal pressure gauge *S*; also an indication of the velocity of gas or gases after passing aperture *B* is transmitted from aperture *T* through conduit *U* to horizontal pressure gauge *S*. It is evident that changes in the velocity of the gas or gases in aperture *B* of sample pipe, produced by the suction of pump *I*, or by pressure in gas main *A*, are controlled, and can be accurately controlled and made equal to the velocity of the gas or gases in conduit *A*, the gas main, such indication being the oil piston shown in glass tube forming a part of the pressure gauge *S*.

The method of operating this apparatus is as follows: The dry gas of the filtering medium *C*, of the receptacle *G*, containing

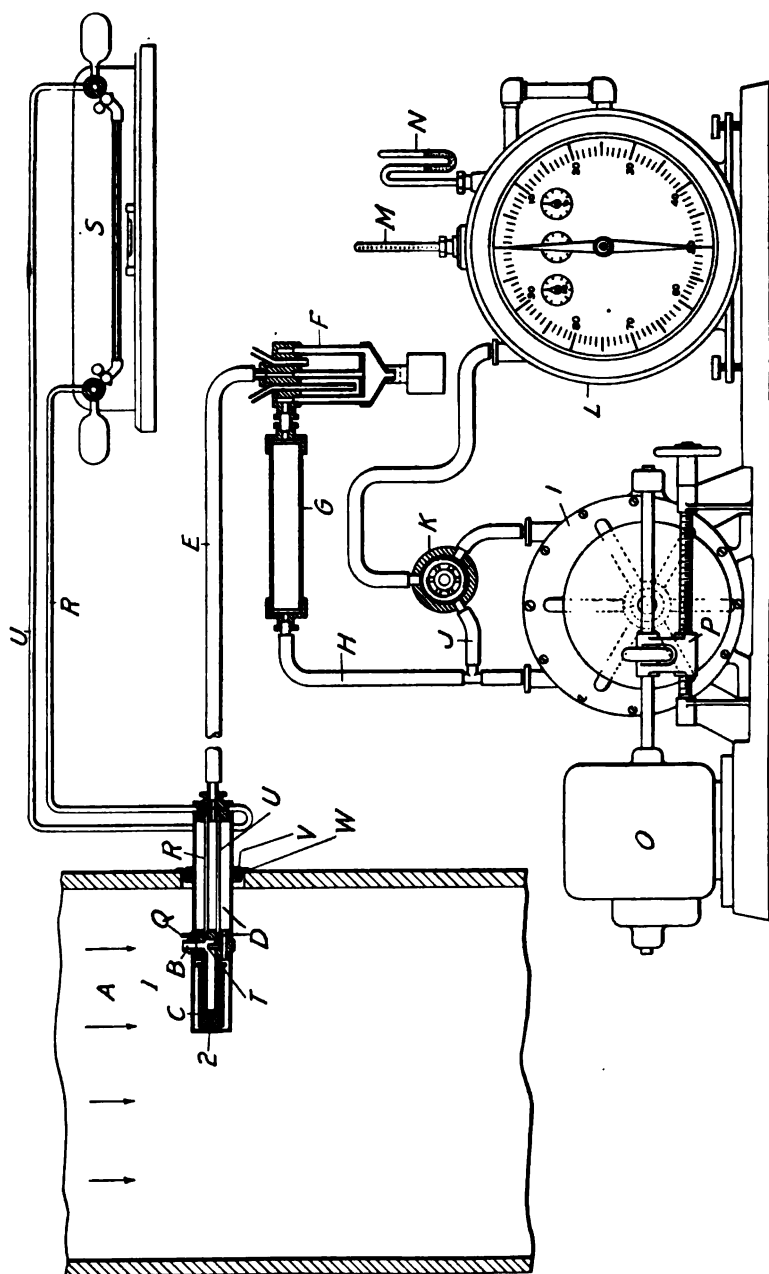


FIG. 26.—THE BROWN DUST, MOISTURE, AND VOLUME DETERMINATOR.

m chloride, and of the measuring flask attached to surface  $F$ , are very carefully determined. They are then inserted in the apparatus, and the sample pipe is then inserted in the gas main, a tight connection being made between flange  $W$  and bushing  $V$ . A reading is noted. At the same time that the sample pipe is inserted in the gas main  $A$ , the time is noted, and the rotary pump  $I$  is started. The speed is then so regulated that the oil piston in the pressure gauge  $S$  is maintained in equilibrium. This insures that the velocity in aperture  $B$  is exactly equal to the velocity in  $A$ , this condition having been determined by a measured flow of gas in gas main  $A$ , and the proper proportioning of apertures in the conduits in the sample pipe during the calibration tests. The condition is maintained for an indefinite length of time and the sample pipe is then withdrawn from gas main  $A$ . The meter reading is multiplied by the ratio of area of aperture  $B$  to area of gas main  $A$  to give the total amount of gas passing through gas main  $A$  in a given elapsed time. The difference between the dry weight of the gas before and after the test, divided by the number of cubic units shown by the meter, gives the weight of dust per cubic unit of gas. The moisture per cubic unit of gas is found in a similar manner. The sum of the weights of the water in drying receptacle and the water caught in the measuring flask attached to surface condenser and the weight of water retained in the filtering medium  $C$ .

#### THE ADVANTAGES OF CLEAN GAS.

The use of properly cleaned gas in hot-blast stoves allows their operation for a year or more without having to take the stoves off for cleaning, while the same stoves would require cleaning at least every three months when using dirty gas. Besides the saving in repairs, greater efficiency is obtained from the stoves, due to the more complete combustion of the gas and consequently a lower loss of the escaping products of combustion. This results in a smaller amount of gas being required for combustion and thus more gas is available for other purposes the amount of gas so saved. Blast stoves are also more efficient, due to the greater readiness with which a clean brick surface transmits its heat to the air for blast than a brick surface covered with dust. The condensation and elimination of water vapor from the gas, incident to the wet cleaning process, is another item in the direction of more perfect combustion, which in the presence of water vapor is retarded. Also, the amount of heat carried into the stack flues is in direct proportion to the amount of water vapor present.

Smaller checker openings can be employed in stoves when using clean gas, thus allowing a material increase in the amount of heating surface of a hot-blast stove. For instance, in Germany, where practically all hot-blast stoves are heated with clean gas, the checker openings are almost universally smaller than in the United States, where most of the stoves are heated with dirty gas. However, the United States is following Germany in this direction of smaller checker openings, particularly at those plants where clean gas is used.

In boiler practice, similar benefits obtain from the use of clean gas, the settings and tubes requiring cleaning at less frequent intervals, with a resultant greater efficiency.

The strains in stove and boiler installations due to contraction and expansion, caused by frequent stops for cleaning when operating on dirty gas, are largely avoided when operating with clean gas on account of the more continuous operation.

In conclusion, it is my opinion that the proper cleaning of blast-furnace gas for use in hot-blast stoves and under steam boilers is very necessary from an economical standpoint, in all cases where the character of the ores and the operation of the blast furnace cause much dust to be blown over from the furnace. For gas engines, the use of thoroughly cleaned gas is imperative in all cases.

The two primary objects of this paper have been :

1. To state the advantages of cleaning blast-furnace gas where dusty gases are produced.
2. To describe the various systems by which the required cleaning can be accomplished.

I have purposely refrained from expressing an opinion as to the relative merits and costs of the various systems described, preferring that prospective users should themselves determine these questions.

ON OF THIS PAPER IS INVITED. It should preferably be presented in person at the meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, a written abstract may be sent to the Editor, American Institute of Mining Engineers, 29 West Street, New York, N. Y., for presentation by the Secretary or other representative of its staff. If a special arrangement is made, the discussion of this paper will close Dec. 1, 1913. Any references to this paper thereafter should preferably be in the form of a new paper for publication in Vol. 1913 (suitable cross references in both volumes).

## The Use of Nodulized Ore in the Blast Furnace.

BY RICHARD HENRY LEE, LEBANON, PA.

(New York Meeting, October, 1913.)

The economies in the blast furnace resulting from enriching the ore are so great, much attention has been paid during the past few years to the various methods of concentrating lean ores, and, as a result, concentrated ore is usually of extreme fineness, various methods of agglomeration and sintering, of more or less value, have been put into practice. The resulting agglomerated concentrates are generated in the form of briquettes or nodules.

Briquettes naturally divide themselves into two classes: (1) those made by the mixture of some binding agent, and then formed into briquettes under great pressure; and (2) those made by sintering of concentrates, the latter either being formed into bricks before sintering or the sintered mass broken into fragments. Of the first class I will not speak, as they are not used on a large scale in this country.

The second class of briquettes, or those made by sintering, are made of melted or fused silicate and oxide of iron mingled with one or less silicates of aluminum, lime, and magnesia.

It is not that the material in a briquette is sintered is proof positive that there are no pores in the material. There are, however, a number of holes of greater or less diameter through the substance of the briquette. They are not pores in the common accepted term as applied to ores by furnacemen, as the sides of the holes and channels are fused. In reality the material is simply sintered. It is practically untouched by the gases in the upper part of the furnace, and the iron has to be reduced by solid carbon in the lower part and hearth. Briquettes sometimes show a little saving in the furnace over an ore mixture of large lumps, but that is not made simply because, owing to the numerous holes and channels through the mass, the briquette is practically composed of small or fine lumps, and, as is well known, the finer the

ore is, the lower the fuel consumption, other things being equal. The limiting condition on fineness is the high pressure developed by the fine ore clogging up the mass of stock in the furnace, and the consequent hanging and slipping, and the irregular distribution of blast.

The value of a sintered ore for blast-furnace use depends largely upon the size and physical character of the individual pieces. It has been proved conclusively with a hard magnetic ore that simply crushing the larger lumps to 1 in. or 0.5 in. in size will materially reduce the fuel consumption. It is also a well-known fact that an ore with a porous physical structure which is readily permeable by gases is preferable to one with a vitreous texture. It is to this class of sintered products that both briquettes made by heat, and nodules belong. Neither have any pores in the proper sense of the word, and consequently both require more fuel than porous ores, such as soft hematites, etc.

The physical structure of any sintered product depends more upon its chemical analysis than upon the process of manufacture. It is not true that nodules are vitreous lumps, and that briquettes have an open and porous structure. That is entirely too broad a statement, for in all products agglomerated by heat the binder is a slag, some combination of an oxide of iron with lime, silica, alumina, or all, and sometimes with magnesia in addition.

If the ore is low in iron, say 50 per cent., then any process of sintering will probably produce a clinker similar to mill cinder; that is, the whole mass will fuse completely. At the other extreme, with a very fine magnetite, for example, it is very difficult to produce any sintering at all. With ores analyzing, say, from 58 to 64 per cent. of iron, the proportion of acid to basic elements in the gangue is very important. With Cornwall ore the most infusible mixture is formed when the quotient of the bases (lime and magnesia) divided by the acids (silica and alumina) is between  $\frac{1}{3}$  and  $\frac{1}{2}$ . The ideal result is obtained when just sufficient slag is formed to bind the grains together in a solid but porous mass.

It is important to have the proper temperature while sintering, and this temperature will of course depend upon the chemical analysis of the materials. It is also important economically to burn the maximum of fuel for the maximum tonnage, and it may therefore be advantageous in certain cases to alter the chemical composition of the material by the addition of lime, or, if the product is a concentrate, by varying the ratio of concentration. Blue billy is one of the easiest ores to treat by any process of sintering, and flue dirt, even after the



parated, will almost invariably fuse to a product resembling  
er.

real conditions for either briquettes or nodules rarely occur  
e, so that, in estimating the value of these sintered products  
mixture, both briquettes and nodules must be taken as  
of about 98 per cent. of mill cinder and 2 per cent. of por-

es from concentrates made in a revolving kiln, when of the  
chemical composition (in the case of nodules made from con-  
Cornwall ore this has been shown by experience to be about:  
 $\text{SiO}_2$ , 8;  $\text{Al}_2\text{O}_3$ , 2;  $\text{CaO}$ , 3; and  $\text{MgO}$ , 3.50 per cent.), run in  
a 0.75 in. in diameter to powder passing through a screen  
es to an inch. The amount of such fines, however, is ex-  
small. Some monthly averages of screen tests taken at  
from our reports show:

|        | No. 1.    | No. 2.    | No. 3.    | No. 4.    | No. 5.    |
|--------|-----------|-----------|-----------|-----------|-----------|
|        | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| 5..... | 21.3      | 40.0      | 27.8      | 38.7      | 15.8      |
| 5..... | 23.0      | 32.0      | 32.3      | 22.7      | 26.8      |
| 5..... | 21.3      | 18.0      | 19.4      | 19.3      | 35.0      |
| 0..... | 12.3      | 5.0       | 9.7       | 8.7       | 16.6      |
| 0..... | 13.9      | 3.0       | 6.4       | 6.7       | 3.2       |
| 0..... | 6.6       | 1.0       | 3.2       | 2.7       | 1.3       |
| 0..... | 0.8       | 0.5       | 0.8       | 0.6       | 0.6       |
| 0..... | 0.4       | 0.5       | 0.4       | 0.3       | 0.6       |
| 0..... | 0.4       | 0.0       | 0.4       | 0.3       | 0.6       |
| mesh.  | 8.2       | 2.0       | 4.8       | 3.9       | 3.1       |

d by the experience of six years that when not more than  
nt. of the nodules pass the 20-mesh screen the very best  
e obtained in the furnace, as to both fuel and production.  
percentage over 0.75 in. in diameter is of no especial advan-  
pt in lightening the pressure of the blast to a slight degree,  
reater the percentage around 0.25 in. in diameter, the better;  
s size the nodules seem to require more fuel. Below it the  
f the furnace is retarded by the increased difficulty of blast  
on and distribution.

se of the nodules depends very greatly upon the composition  
, as above stated. Sometimes when a lot of lean ore is de-  
o the concentrator the resulting nodules may run as low as  
nt. in iron, with a corresponding increase in the percentage  
e, but the nodules are always quite coarse; as much as 60  
will remain on the 0.75-in. screen. In this case the blast  
will at once lessen and the furnace will drive faster.

Again some rich ore will go through the concentrator, bringing the iron in the nodules up to 60 and even 62 per cent.; in this event the nodules will be much finer; sometimes as much as 30 per cent. will pass through the 20-mesh screen. After the furnace has been filled for 6 or 8 hr. on this mixture the pressure will go up, the driving will slacken, and unless precautions are at once taken the sulphur in the iron will run up, and there may be sticking and hanging unless the pressure be kept down to reasonable limits. As the Pennsylvania Steel Co. at its Lebanon plant runs almost all the time upon low-phosphorus, low-sulphur iron, with whatever silicon the customer demands, it is of great importance that conditions in the furnace be kept regular. The Cornwall ore itself as delivered to the concentrator will vary from 30 per cent. iron to 45 per cent., with similar variations, of course, in the gangue. To get an absolutely regular product commercially and under working conditions with such varying ore is manifestly impossible, but by attention and study the nodulizing plant has reduced the variations in the iron content of the nodules to an average of from 56 to 60 per cent., and by using a series of holding pits for the concentrates the daily variation in the nodules is rarely over 2 per cent. in iron, with corresponding differences in the amount of gangue. The ratio of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{CaO}$ , and  $\text{MgO}$  among themselves varies hardly at all, so the net result of variations in the iron of the nodules means an equivalent change in the free  $\text{SiO}_2$  to be fluxed. As practically all the iron made at the Lebanon furnaces must be low in sulphur (below 0.035), and the silicons demanded are generally low, it is of the greatest importance that the composition of the slag be kept regular, especially so as the coke runs rather high in sulphur, requiring a basic slag at all times, even when on high-silicon iron.

To enable the furnace department to know the composition of the nodules before they are charged into the furnace, the Superintendent of the concentrator, Mr. McKechnie, has his samplers take a sample from the nodule kilns every hour. These samples are mixed, and every morning a sample from this mixture is taken to the laboratory for analysis, and the result is sent to the furnace office. By this means, before the nodules are filled into the furnace their composition is known, and any change in the lime required is made. No attention is paid to the variations of the iron. Generally speaking, the same fuel is required whether the nodules run 56 or 60 per cent. The leaner nodules, being larger, take more fuel, while the richer ores, although more easily smelted because finer, yet pack more than the coarse, making the gas distribution less perfect, which in turn

the demand for fuel, so that practically we find little or no between 56 and 60 per cent. nodules. The Lebanon plant Pennsylvania Steel Co. is the only one that runs a furnace upon nodules, and consequently a few remarks upon the of such a furnace may be interesting.

Furnace at present in blast is 80 ft. high, 11 ft. 6 in. hearth, 10 ft. bosh, with 13 ft. stock line, filled by a skip with bell emptying over the hopper. The bell lever projecting over the top of the hopper has a tendency to create a channel through the charge, owing to its intercepting the materials falling upon it and the larger lumps of coke to roll under it. This, however, we overcome more or less successfully by means of baffles and other means. We use 10 6-in. tuyeres, and on an average about 30,000 cu. ft. of air per minute is blown, which is nearly the usual quantity needed for a furnace of that size on porous ores. Indeed, we find that 30,000 cu. ft. is not too much as far as fuel consumption is concerned when more than 30,000 cu. ft. of air per minute is put into the furnace the loss in fine nodules blown out of the top is extremely small. The slight gain from increased tonnage is offset by an increase in the amount of nodules required per ton of iron.

The concentrating and nodulizing plant at Lebanon was installed to treat the ores used were entirely roasted Cornwall magnetite, running generally from 30 to 45 per cent. in iron, from 12 to 25 per cent. in  $\text{SiO}_2$ , and alumina, lime, and magnesia in varying amounts, depending upon the amount of acid present, so that, as far as the nodules are concerned, they are relatively to themselves and to the acids, so that, as far as the nodules are concerned, the free silica present determines the amount of lime to be added to or taken off the charge. Fortunately, Cornwall ore contains a considerable amount of magnesia, which largely increases the fluidity of the cinder. Were it absent, running a furnace on all iron ores would be almost impossible, as in 24 hr. the silica and iron in the cinder may change from 48 to 38 per cent., and with 8 to 12 per cent. of magnesia the low silica-slag would be very sticky and stiff that it would not run through the cinder.

In fact, the presence of magnesia in the Cornwall ore not only enables a furnace to run alone on this ore, but renders it possible to run a low-silicon iron with low sulphur. Often with both roasted ore and nodules it is necessary when the coke is high in sulphur to run for months at a time on a cinder carrying only from 8 to 12 per cent. of silica and alumina, and such a cinder would not run up a furnace were it not that the magnesia renders such a cinder in spite of its basicity, as liquid and as free-flowing as the cinder with 48 per cent. cinder with lime alone as a base.

In addition to the daily nodule analysis, we also watch the coke very closely, both as to the quality of the coal used and as to the sulphur and ash. From the nature of the coke operation (we use Semet-Solvay by-product coke, with ovens at the plant); it is not possible to secure an analysis of the coke before it is charged into the furnace, but the ash does not vary much; the sulphur, while high, is also pretty regular, but the coals used do at times vary greatly in the mixture, although we use every endeavor to keep the coal mixture as regular as possible. This regularity in coal mixture I regard as the most important single item making for success in blast-furnace operation, not only in making low-sulphur iron from high sulphur materials, but with all ores on all kinds of iron. This point has not had the attention paid to it that nearly all the other elements concerned in making iron have had from time to time, but in my opinion, based on nearly 30 years' practical direction of blast furnaces, nine-tenths of all furnace troubles would disappear were it possible to always give a furnace a well-burned coke made from a regular unvarying mixture of coals.

A report of the different tonnages of coal charged each day is sent to the blast furnace office every morning, and as that coke is not pushed until the next day, we know exactly what mixture is in the furnace, and when any coke of a changed mixture will be filled. As different coals, even when the oven temperatures are the same, differ enormously in the quality of coke they make, this knowledge is of great value, and enables the furnace superintendent to take any measures he judges best to meet the change. The hardness of the coke made is of great importance in the successful working of nodules.

The nodules themselves, being a fine ore, fill more or less the openings between the pieces of coke, and if the pieces of coke are soft, and crumble with a large percentage of breeze, it can easily be seen that the blast will have great difficulty in penetrating and distributing itself through the resulting mass. On the contrary, with hard coke and coarser nodules no difficulty whatever is experienced in using all nodules; the pressures are not high, the fuel is moderate, and the furnace works far more regularly than with Mesabi ores. In fact, all difficulties in working nodules come from softness of the coke and the fineness of the nodules. Where these two elements are absent, a furnace will work as well on nodules of any chemical composition as on any other iron-bearing ore. The chemical composition of the nodules can be taken care of by proper fluxing, but for packing in the furnace through soft coke or excessively fine nodules there is no remedy whatever, and where these two conditions hold

will never run so successfully on all nodules as on gas-ore or ore in lumps.

Amount of fuel needed per ton of iron made from nodules, as burned by-product coke made from a mixture of mountain and gas-ore, is from 2,800 to 2,400 lb. in good practice. Little iron is made by the gases because of the nature of the nodules, which are lumps of mill cinder, requiring solid carbon for reduction; the coke happens to be soft the fuel will increase enormously, the amount being consumed in the upper part of the stack by the blast. With first-class Connellsville beehive coke the fuel would be less, because we have generally noticed that whenever we have used Connellsville coke the silicon in the iron will jump up, the percentages being raised from around 1.5 to 2.5 per cent. in the casts made with the Connellsville coke.

One important point in working on all nodules is the location of the melting point. When too low, although the silicon may be high, the furnace hot, yet the gases will be thin, the pressure low, and the furnace will slacken in driving to hardly more than the usual gait. On the other hand, a too high melting point will give gases which, while extremely abundant, will burn inefficiently on account of their dustiness. The pressure will be low, not normal, and the driving very fast, but the burden carried is less than in the best conditions, the hearth cooler, and the iron is kept down in the iron with great difficulty, but with a good yield of iron.

These conditions depend entirely on physical causes. In the first instance, the melting or rather sticky point is in the bosh or lower part of the furnace, and the area there being contracted gives fewer passages for the blast to go through the sticky mass. In the second case, where the melting point is high, the area of the furnace is greater, affording more passages for the gases, and consequently the pressure is less. The important point is to have this melting point at just the right height, which can easily be told by the behavior of the furnace, its fuel economy, and its production of iron.

Variations in fineness in the nodules require pretty careful attention to the penetration of the blast, and to find out whether the blast is uniformly distributed over the tuyere area the old-time test is to drive a bar quickly as possible, allowing it to remain for 2 min., without heating it rapidly, and examining the bar to see whether it is uniformly heated, or hotter in spots. With nodules it seems to be even

more important to have a uniform heat over the tuyere area than with ores reduced by the gases. The gases themselves are, like all furnace gases made from hard non-porous magnetites or mill cinders, very low in  $\text{CO}_2$  and high in  $\text{CO}$ , the ratio between the  $\text{CO}_2$  and  $\text{CO}$  being from 1:4 to 1:6 instead of from 1:1.8 to 1:2.5 as with gas-reduced ores; consequently they are much less inflammable, and gas explosions are very rare or unknown while the blast is on the furnace.

With nodules, as with all other ores, a moderate-sized furnace seems to be more economical than the jumbos. All difficulties from soft coke and fine nodules are increased when our 100-ft. furnace is working on all nodules, and harder coke and coarser nodules are required for success than with the 80-ft. furnace.

In conclusion: with a hard regular coke, and nodules of which 95 per cent. will remain on a 20-mesh screen, there are no especial difficulties in working on all nodules, provided some procedures dictated by experience and probably different at every plant are observed. With soft coke and very fine nodules trouble will be had at any furnace and under all conditions of management.

The slag volume required for working with nodules is, within reasonable bounds, not very important.

DISCUSSION OF THIS PAPER IS INVITED.—It should preferably be presented in person at the meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, a discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West Street, New York, N. Y., for presentation by the Secretary or other representative of its members. Unless a special arrangement is made, the discussion of this paper will close Dec. 1, 1913. Any further discussion thereafter should preferably be in the form of a new paper for publication in Vol. 40, with suitable cross references in both volumes).

## Use of Pulverized Coal as a Fuel for Metallurgical Furnaces.

BY H. B. BARNHURST, ALLENTOWN, PA

(New York Meeting, October, 1913.)

It would be a difficult matter to trace from the beginning the very improvements made in the burning of fuels prior to 1860. Doubtless the crossing of the sticks of wood in building a wood fire early led to our savage ancestry as a means of expediting its effective use in their crude culinary purposes. Stones and andirons came into use assisting the admission of air to the under part of the fuel. Tile beacons and cressets utilized metal bars as supports for the fuel for the purpose. It is probable that Tubal Cain owed his success to the use of bellows making possible the use of mixed fuel and wood upon a hearth. With the development of working in cast iron, cast-iron bars came in, and they are still with us doing duty in the household and almost every art where heat is a factor.

Nothing was done beyond these crude methods prior to 1860. With the advancement of knowledge came the fuel-gas producer, a natural development of the retorts employed in supplying illuminating gas. It was only within the last 15 years that the conclusion became general that complicated systems for saving heat would not remedy deficiencies in its primary development, and within that time there has been great advancement in the means of producing initially a fire of high efficiency, so that to-day we are moving rapidly toward both high development and high absorption, with the resultant of high efficiencies.

Regarding the subject of the availability of pulverized coal as a fuel, one may occur to ask, why has this not come up earlier? This question would be naturally prompted by recalling the fact that the first of Crompton's English patents upon his methods were issued nearly 40 years ago. A conclusive answer to this, however, is that Crompton at that time had very crude facilities for making coal gas at best a very imperfect pulverization of the coal, and the method of preparation was very great. He does not seem to have been aware of the advantage of a thorough drying of the coal in the

effort to reach high efficiencies. In short, while the possibilities of high results were indicated, the means of reaching them was left for later developments.

It was not until the pressing demands of the cement industry for a low-priced fuel of high efficiency became imperative that pulverized coal was found to fulfill almost ideal conditions. In this industry the grinding of cement materials cheaply, to a high degree of fineness, was early found to be a necessity. The finer the grinding the better the cement produced by it. So pulverizing coal as a fuel fell naturally into the hands of men able to powder cheaply a material much less refractory than cement rock or clinker, and to the degree of fineness which would show the best results.

It was early noted that the more thorough the drying and the finer the coal was ground, the higher the results. Of course, there is a limit of practicability.

Coal properly ground will burn thoroughly if 85 per cent. passes through 200 mesh and 95 per cent. through 100 mesh, the measuring screen apertures squaring  $\frac{1}{16}$  and  $\frac{1}{8}$  in. respectively. I use the term "properly ground" to express the condition that the coal thus pulverized shall contain a high percentage of ultimate fine dust practically unmeasurable.

The author has found in such properly ground coal a percentage above 70 capable of passing through 300-mesh screens, squaring  $\frac{1}{16}$  in. on the side. It may be presumed that these percentages progress relatively in the further reductions contained, as the larger screens, of course, pass all such fines without rejections. There appears to be no practicable means of measuring the highly divided particles.

As we can burn all the coal thus prepared, including the rejections when the percentages named pass the 200-mesh and 100-mesh screens, there seems to be no good reason for pushing pulverization beyond this point. Coal can be cheaply brought to this condition and the mills able to do this work have large capacity. Higher percentages may be reached by the sacrifice of capacity, and consequently economy. This standard of 85 per cent. through 200 mesh and 95 per cent. through 100 mesh is a practicable commercial standard and should be maintained.

It may not be amiss at this point to describe the conditions contributory to the high success attendant upon the use of pulverized coal in cement kilns. Two objects are in view in this part of the cement-making process: 1, driving off of the carbon element in the carbonate of lime used as a material; 2, the subsequent formation of clinker nodules by partial vitrification.



inclined kiln, say 7 ft. internal diameter and 140 ft. long, the material is delivered at the top of the incline, which it descends by the rotation of the kiln. The carbon of the lime is driven off by comparatively low heat, after which the charge approaches the zone of greatest thermal activity and is there "clinkered," or solidified, at a very high heat. The fuel is fired at the lower end of the kiln and passes up in reverse direction to the progressing charge coming down. The walls of the kiln, as well as the charge, receive the heat of the passing gases and communicate it in degree to the charge when by rotation the hot walls pass under it. The zone of greatest activity is some 10 to 30 ft. from the point of fuel admission.

At the lower end of the kiln, immediately adjacent to the fuel admission, there is but little heat directly from the fuel, but it is nevertheless heated from the mass of nodulized clinker coming at high heat through the hot zone and heating the kiln walls by transmission. The temperature is estimated to be from 2,900° in the hot zone to 2,000° at the point of discharge.

The clinker cascades as it advances through the rotating kiln. This is done at the lower end of the kiln a heated chamber into which the charge is directed, so that deflagration takes place quickly.

This heated chamber is a condition that must be imitated in an attempt to burn the fuel in other conditions. Cement burners, however, do not attempt to deflagrate the coal close to the nozzle of the entrance.

Their control of the admission of air is not complete, hence the heat is upon the heating of the air coming in mainly at the discharge opening, passing there over the clinker and subsequently through 10 or 15 ft. of the heated kiln. This assists in cooling the clinker somewhat and in preheating the admitted air which subsequently supplies combustion.

Cement burners make little attempt to control the volume of the air. It is difficult under the existing conditions. There is no doubt that better results would attend such control.

Justification for this extended description of the process of burning, the author submits that of the 90,000,000 barrels of clinker which will probably be produced in 1913 in the United States, 2,000,000 barrels are being burned with pulverized coal as fuel.

As the average quantity of coal burned is at least 100 lb. per barrel, or 20 barrels burned with 2,000 lb. of coal, the total use of pulverized coal in this industry amounts to at least 10,000 short tons per 24 hr. This, coupled with the fact that it is not unusual for cement kilns to be in continuous operation for from 12 to 15 years,

months, would certainly establish confidence and remove doubt as to the reliability of this use of coal.

Undoubtedly the proper method of firing pulverized coal is to admit with the fuel the exact quantity of air necessary to the result to be attained, as shown by observation, and to maintain the relationship between the fuel and air quantities as long as conditions desired are being fulfilled.

This matter of complete control of the two factors, fuel and air, is and will be at the root of all success with pulverized or sprayed fuel in metallurgical processes.

It is unfortunate in the present state of our arts that it is difficult to obtain very exact readings of the temperatures attainable in the burning of fuel. We do know, however, that a certain quantity of air will deliver the oxygen required to give the highest attainable heat from a given fuel. With a knowledge of the components of a fuel, the laws of thermo-chemistry inform us not only of the quantity of oxygen we must have, but the theoretically attainable temperatures.

Applying these laws further, we learn that any air or oxygen supplied in excess of these requirements simply dilutes the products and lowers the temperature; also, that insufficient air and oxygen will burn part of the fuel to  $\text{CO}_2$  and part of it to  $\text{CO}$ , and with the air supply halved we obtain only the poisonous and inflammable  $\text{CO}$ . However short we may be of pyrometers, there is in the eye of the intelligent operator a gauge which tells him at a glance whether the heat he has is serving his purpose. Pulverized fuel has a great advantage in this respect.

It need not be supposed that an operator must be perpetually adjusting his apparatus. If we find that with the air-gate fixed at a certain opening the fire is too hot, a simple reduction in the quantity of fuel admitted lessens the source of heat and changes the ratio of the air to the fuel. If not hot enough, more fuel gives more heat units entering and a lessened excess of air, resulting in a heightened temperature.

In all probability, it will be found that excess air must be admitted constantly to keep the heat from reaching destructive limits. With control of both the quantity and quality of heat, this danger is negligible.

If we consider the burning of coal as shoveled or fed in bulk, it must be conceded that a certain degree of comminution or pulverization takes place in the fire as a necessity of combustion. Coal does not burn in lumps, but its ash comes away pulverized, and this gradual pulverization occurs in the fire at the expense of some of the heat

the work done. As this is done slowly, it is often necessary to have a large grate area so that the collective surfaces exposed for the development of heat shall be sufficient for the purpose for which the fuel is used.

When classed as a fuel a material must be able to give out more heat than it receives. No fuel will burn until its particles are brought to a self-supporting condition by the heat absorbed from some other substance previously burned. Not only this, but the oxygen must be brought to a combining temperature. This involves equally the accompanying nitrogen. This heat must be passed from one substance to substance in increments small in themselves but collectively large as the occasion demands.

In the use of pulverized coal, therefore, we have best prepared this for the absorption and evolution of heat, but in addition we prepare the air by practically a similar subdivision for joining in the

sequence of events in combustion is now conceived to be as follows. The volatile carbonaceous elements of the fuel are first disengaged, producing highly combustible hydrocarbons, and these in combination with the oxygen, burning to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ , disengage enough heat to cause the same sequence of happenings to the solid carbon components. This reasoning seems to be credible, and upon the heating not only of the substances of the fuel but of the oxygen, all of which must be raised in temperature to the point at which heat development can proceed in excess of heat absorption. It is not to be evident that comparatively large masses of fuel supplied with large volumes of air will, for reasons simply mechanical, fail in combustion. This is more particularly so where a large content of volatile matter is set free by contact with another mass of incandescent heated surroundings. Under such conditions it would seem to be possible to get the best results from any fuel. The sweeping off of volatile gases by large volumes of insufficiently heated air produces smoke. This smoke represents but a small weight of unburned fuel, but indicates a condition in which gases of large volume pass off uncombined. A heavy draft pressure accentuates this condition, and records are plentiful of a large passage through the oxygen which has failed of its duty from lack of heat as pre-requisite to combination. Carbon monoxide is necessarily liberated in an atmosphere of incombustible gases deficient in oxygen, rendering difficult the further establishment of active combustion.

It does not require many moments' thought to perceive that a pulverized fuel, the particles of which are each surrounded by a minute

envelope of air, sufficient to thoroughly burn it, is an ideal fuel under ideal conditions. In projecting thus a cloud of fuel into a highly heated chamber, each particle because of its opacity becomes an absorbent of heat radiating not only from the chamber walls, but from each neighboring particle as it inflames. This inflammation progresses with rapidity almost inconceivable. Pulverized fuel injected thus with its air supply at a speed of several thousand feet per minute inflames right up against the delivery nozzle, the flame playing about its mouth. This is best accomplished by avoiding high pressure for projecting the fuel. The final mixture of air and fuel is at the instant of projection into the furnace.

It must not be forgotten that an expansion of volume takes place in the air carrying the fuel as soon as it is heated. This expansion is of course based upon the related absolute temperatures and explains the large volume assumed by the flame on leaving the point of entrance. Excess air so carried partakes also of the expansion.

The temperatures usable cover a range of nearly  $2,000^{\circ}$ , or from about  $2,000^{\circ}$  to  $4,000^{\circ}$ . By ordinary manipulation as described, the temperature and quantity of fire can be changed as easily as the turning on or off of a gas jet. The response is instantaneous. This particular feature renders the use of pulverized fuel particularly suitable in metallurgical furnaces. It has been found so in steel and iron working, being to-day in the following uses: ore roasting, flue-dust nodulizing, open-hearth furnaces, puddling furnaces, busheling furnaces, heating furnaces, forge furnaces.

The main difficulties in the earlier and experimental stages were caused by: 1, not drying the coal; 2, poor pulverization; 3, the carrying of too high temperatures; 4, the use of ports too small, giving the gases too high velocity.

With a knowledge of how much air is required with a given amount of fuel to produce a given temperature, and a knowledge of the volume of gases so produced, it is easy to proportion the ports both of inlet and outlet so that a scouring blow-pipe effect may be avoided. The excellent practice already attained is undoubtedly due to the application of this knowledge.

Aside from the advantages attainable in the higher efficiency of the fuel, there are a number of things which in actual service contribute to the profitableness of its use.

The furnace begins its work almost instantly and with whatever degree of intensity may be desired. There are no periods of lowered temperature due to firing cold fuel. There is no cleansing of fires for puddling or heating, so that operation is practically continuous. There

under formed in puddling and heating furnaces, which is dis- in the usual way. The most of the ash passes out of the and floats away lightly. The neutral ash content within e limits does not affect the fire appreciably.

been somewhat difficult to obtain from large users close data g the performances of the various furnaces. Perhaps the ence of success is the continuance of use and the enlarge- plants now going on in extension of business upon the same he author is able, however, to submit the following authentic

ting carbonate ores of high sulphur content, the carbon has en off and the sulphur reduced within permissible limits by f less than 7.5 per cent. of fuel upon the weight of the charge. blem involves the maintenance of a low temperature, about ., to prevent the agglomeration of the ore fines into masses. e practice obtains in the roasting and nodulizing of ores and where the heat is maintained sufficient to permit the ore to ules or balls, but not to stick to the walls of the roasting

n-hearth practice with pulverized coal, steel is being made fuel at the rate of from 450 to 500 lb. per net ton of pro- his is an average of 45 heats, the fuel and product being weighed.

figures were obtained during a continuous run of six weeks. ace was operating beautifully when visited by the author, echanical difficulty had been experienced. The melts were in slightly less time than with oil, which had been used pre- An analysis of the slags produced with each fuel is as

|                                     | Oil. | Coal. |
|-------------------------------------|------|-------|
| SiO <sub>2</sub> .....              | 16   | 16.5  |
| FeO.....                            | 22   | 18.2  |
| MnO.....                            | 7.4  | 6.7   |
| P <sub>2</sub> O <sub>5</sub> ..... | 1.7  | 1.9   |

alysis of the steel :

|              |                |               |
|--------------|----------------|---------------|
| Sulphur..... | 0.025 to 0.035 | 0.035 to 0.04 |
|--------------|----------------|---------------|

n coal, 1 to 1.15 per cent.

appears here to be no more difference than would occur he variations of the charge and of the fuel.

ddling furnaces the fuel supply varies with the season, the ther of spring and fall permitting a larger output than when hot weather affects the men tending the furnace. It is safe at iron can be puddled at an average expense of 1,200 lb.

pulverized fuel per gross ton of muck bar produced; in fact, less than 1,000 lb. of coal per gross ton of bars has been shown in practice during periods when favorable temperatures and continuity of work conduced to high economy.

In heating furnaces and busheling furnaces there is some latitude of performance, due to varied charges placed in the furnaces and to the size of mill served by them. The average consumption of pulverized fuel in heating furnaces seems to be from 500 to 550 lb. of fuel per gross ton. The busheling furnaces require from 550 to 600 lb.

To obtain such results, however, the furnaces must be properly proportioned and equipped and in good condition. It must not be expected that the results obtained by simply squirting coal of greater or less degree of pulverization into a furnace, with an unmeasured jet of air, will equal the practice here shown. The figures given are authentic and may be relied upon. Success insists upon dry coal, fine pulverization, proper air supply.

Another factor is that the attendants should be interested in the production of high results. Men of a good order of intelligence operating mechanism which displaces the shoveler and the wheelbarrow man, and who are constantly on the "firing line," both practically and metaphorically, are extremely valuable in this art. The operations, however, are simple and the manipulations few and rational in their nature. With such men further advances may surely be looked for.

The procedure followed in the proper preparation of pulverized fuel, as well as delivering it to the furnace, is as follows:

The coal is received in the pit of an elevator, into which it is dumped from the cars. The elevator carries it to the hopper of a pair of crushing rolls. The coal after passing through these rolls may be weighed by automatic recording scales.

The coal should also pass over a magnetic separator at this stage to remove iron or steel scrap in the shape of nuts, bolts, pick points, wedges, and such foreign matter, which would interfere with the pulverization.

The coal is next introduced into a drier to expel the moisture. A good drier of approved design will remove 6 lb. of moisture per pound of fuel used in firing the drier and the product will ordinarily carry less than 1 per cent. of moisture. From the pit into which the dried coal falls from the drier, it is elevated to bins above, from which it is evenly fed by spouts and feeders to the pulverizing mills. These mills, if of proper construction, grind the coal rapidly to the degree of fineness required.

pulverized coal is led to the pit of an elevator, which carries a conveyor which distributes it to the coal bins, from which it is carried by gravity to the pipes leading to the burners.

It is well to note at this point that pulverized coal should always be carried as a solid and not as a dust-cloud. To convey it by a stream of air insures the existence of a mixture of air with the coal, a state in which it is dangerous, while if leaks in the apparatus and its surroundings become insupportably dirty. The delivery of coal in this form also makes necessary some form of settling or settling chamber wherein the coal may reappear as a solid. The requirement of velocity in the air current sufficient to float the coal causes an expenditure of power greatly in excess of that required by properly constructed elevators or conveyors.

The bins for holding the coal are proportioned to carry sufficient coal to serve the furnace during intervals in which the mills may not be running. For instance, coal may be ground and stored for 24 hr. consumption by running the mills for 10 hr.

Coal is fed from the bottom of the bin by a worm feed screw driven with a variable-speed drive, so that the furnace may receive coal as desired. The coal falls freely from the feed screw delivery into a closed pipe, mixing with air in its descent in preparation for entering the burner pipe.

The burner pipe is so formed that the air passing through it from the bottom not only projects the fuel into the furnace, but also, while doing so, acts as an injector in drawing with it the descending column of air, thus entraining the entrained coal from bins above. The fuel there is completely mixed with the ultimate column of air entering the furnace. The speed and volume necessary for the proper furnace operation are predetermined from known data.

The air flow is controlled by the fan speed or by gates, or by both, and the fuel flow by the number of revolutions of the feed screw per minute. The operator adjusts these factors to the quantity and intensity of the fuel required, and by inspection at times sees that the conditions remain satisfactory.

The construction of the furnace is not materially changed. The operating cost in the furnace room is very low indeed, as one man can oversee a number of furnaces. The furnaces are so varied in construction and operation that it is not fairly in the scope of this paper to discuss them. It must suffice to state that any solid fuel can be dried and pulverized and can reach its highest efficiency in the furnace, and for this reason fuels hitherto deemed unavailable, such as coke breeze, lignite culm, and anthracite culm, may be now

looked upon favorably as responsive to the call for cheapness in the source of heat.

Regarding the actual practice in the use of pulverized fuel, the ease with which it is burned has been to a certain extent a drawback rather than an advantage. This is a statement paradoxical in its nature, needing explanation. The novelty of the method is so attractive that those experimenting with it are at first satisfied with producing a good fire with simple apparatus in which may exist no such means of control as are necessary to the accomplishment of the best economy.

It is no success to use twice as much fuel as the work at the time may require, nor is it a success to drive a small fire to a destructive intensity to make good defective proportioning.

The proportioning involves knowledge of the heat requirements of the job. The amount of fuel necessary may be ascertained and the volume and velocity of the air supply computed. With this comes necessarily a prescription of the volume of the furnace, that combustion may have time for its completion. The proper size of ports taking off the gases, the size of the chimney, and the velocities of the gases, should all be as carefully determined for pulverized fuel as for gas or oil. A simple experimental trying out, with a defective link in the chain of conditions, should not be regarded as conclusive.

With proper predetermined proportioning of the apparatus, the operation will be elastic or adjustable to a wide range of performance under a very nearly constant percentage of efficiency. This is unattainable in an installation which may or may not be proportioned to the production of high efficiency at any particular duty. For this reason the ease with which pulverized fuel may simply be burned does not assure that the best results are being obtained.



ON OF THIS PAPER IS INVITED. It should preferably be presented in person at the meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, an abstract in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West, New York, N. Y., for presentation by the Secretary or other representative of its Board. If a special arrangement is made, the discussion of this paper will close Dec. 1, 1913. Any paper presented thereafter should preferably be in the form of a new paper for publication in Vol. 40 (suitable cross references in both volumes).

## for Use in Connection with Wet and Dry Bulb Thermometers in Making Psychrometric Determinations.

BY CLARENCE P. LINVILLE, EVERETT, PA.

(New York Meeting, October, 1913.)

An article published in the *Iron Trade Review*,<sup>1</sup> I gave a recommendation for the installation of wet and dry bulb thermometers for use in making moisture determinations in the air being drawn into a blast furnace, and also gave a chart for use in obtaining moisture values from the thermometer readings. The data from this chart was prepared were obtained from the tables in use at the U. S. Weather Bureau.<sup>2</sup> The work of Carrier<sup>3</sup> has shown that the tables are somewhat in error. He has recalculated the values for moisture as referred to wet and dry bulb thermometer readings, and has prepared a psychrometric chart from the values thus obtained.

This work has placed the subject of psychrometry upon a scientific basis. I think it is proper that we should recognize the importance of his work and give him credit for one of the most important and valuable researches that have been published in recent years.

At present blast-furnace men are not ready to use, as he suggests,<sup>4</sup> a value for moisture in grains of water accompanying a pound of dry air. For the most convenient this may be for heating and ventilating work. For engineering problems, there are several reasons for preference for the use of a value expressed in grains of water in a cubic foot of air and water vapor, in connection with combustion phenomena and the effects of moisture on blast-furnace operation. Previous papers presented to the Institute have used such values and we have

1. *Determining Moisture in Air Blast*, *Iron Trade Review*, vol. xlvii, No. 26, p. 1205 (October, 1910).

2. *Bureau Bulletin No. 235*, U. S. Department of Agriculture.

3. H. Carrier: *Rational Psychrometric Formulæ*. *Transactions of the American Society of Mechanical Engineers*, vol. xxxiii, pp. 1005 to 1039 (1911).

4. Discussion of paper by Bruce Walter, *An Improved Method of Drying Air for Blast Furnaces*. *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxviii, No. 4, p. 10 (July, 1912).

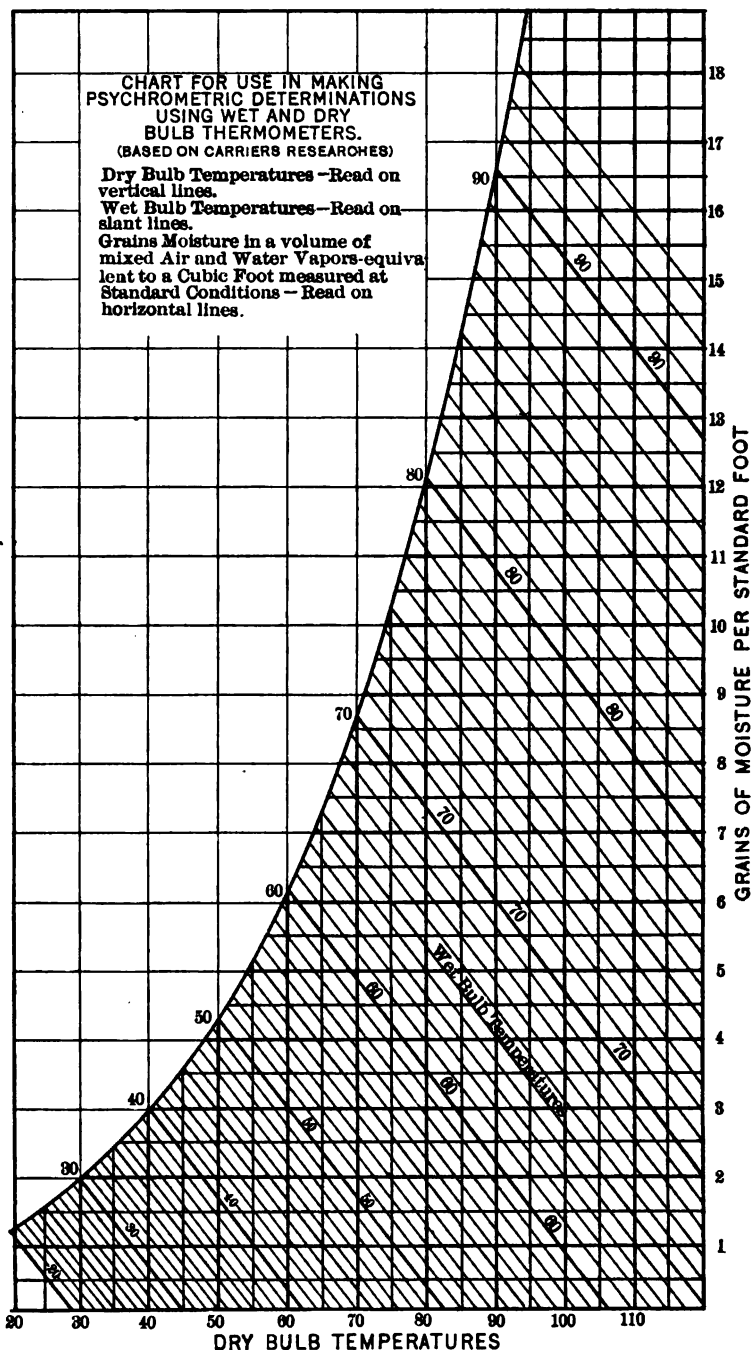


FIG. 1.—CHART FOR USE IN MAKING PSYCHROMETRIC DETERMINATIONS.

somewhat familiar with the effects of moisture, as expressed of grains per cubic foot of air, on furnace operation.

It can be shown that the theoretical temperature of combustion of fuel varies in almost exact proportion to the amount of moisture in a cubic foot of the mixed air and water vapors, while the problem becomes much more complex when the amount of water is expressed in grains accompanying a pound of dry air.

For these reasons, and also because of a desire for a convenient reference use in my own investigations, I have thought it worth while to prepare a chart, basing it upon the work of Carrier, but making the necessary modifications so that the readings will give, when used with temperatures taken with dry and wet bulb thermometers, values expressed in grains of moisture actually present in a cubic foot of mixed air and water vapors, which will be equivalent to the amount of moisture in a cubic foot measured at standard conditions of temperature and pressure (32° F. and 29.92 in. barometer).

It may be noted that the method used in obtaining the values for preparing this chart was as follows:

Mr. Carrier states that a correction of 1.5 per cent. of the difference between the dry and wet bulb readings should be made by subtracting this amount from the wet bulb temperature,<sup>5</sup> to correct for radiation. In all computations made took account of this correction and accordingly the chart can be used without the necessity for making a correction of thermometer readings. It should be stated, however, that it is necessary to maintain an air velocity over the thermometer bulbs of approximately 2,000 ft. per minute. Thus, for example, if the reading of the wet bulb should be 80° with a dry bulb temperature of 110°, the corrected readings would be 79.55° and 110° respectively. Hence in preparing the chart the value used for 80° and 110° was obtained by using the reading given by Carrier's chart for 80° and 110°.

The value so obtained gives grains of moisture accompanying a pound of dry air, it is necessary to reduce it to grains in a standard cubic foot of the mixed gases. This was done by determining the volume of water vapor in cubic feet, standard conditions, adding it to the volume of a pound of dry air, standard conditions, and dividing the sum by the number of cubic feet of mixed gas. This value gives grains of water vapor in a volume of mixed air and water vapor such as would give a cubic foot of the mixed gases at standard conditions.

These values were computed so that a sufficient number of points

<sup>5</sup> Private communication from W. H. Carrier.

could be located for the construction of a chart, and these values were plotted, and the chart constructed as shown.

As an example of the use of the chart, let us assume that the dry bulb reading is  $110^{\circ}$  and the wet bulb reading is  $80^{\circ}$ . Reading on the horizontal line we come to the vertical line reading  $110^{\circ}$ . Following this line upward until it intersects the slant line marked  $80^{\circ}$  and then reading over horizontally, we find that the readings indicate 8.07 grains of moisture per standard foot.

In case it should be desired to convert these values into grains of moisture in a cubic foot of mixed vapors at any other temperature than  $32^{\circ}$  the following table is given :

| Temperature.<br>Degrees F. | Factor. | Temperature.<br>Degrees F. | Factor. |
|----------------------------|---------|----------------------------|---------|
| 0 .....                    | 1.0669  | 65.....                    | 0.9370  |
| 5 .....                    | 1.0582  | 70.....                    | 0.9281  |
| 10.....                    | 1.0469  | 75.....                    | 0.9195  |
| 15.....                    | 1.0358  | 80.....                    | 0.9109  |
| 20.....                    | 1.0250  | 85.....                    | 0.9025  |
| 25.....                    | 1.0144  | 90.....                    | 0.8943  |
| 30.....                    | 1.0041  | 95.....                    | 0.8862  |
| 32 .....                   | 1.0000  | 100.....                   | 0.8783  |
| 35.....                    | 0.9916  | 105.....                   | 0.8706  |
| 40.....                    | 0.9840  | 110.....                   | 0.8629  |
| 45.....                    | 0.9742  | 115.....                   | 0.8554  |
| 50.....                    | 0.9646  | 120.....                   | 0.8480  |
| 55.....                    | 0.9552  | 125.....                   | 0.8407  |
| 60.....                    | 0.9460  |                            |         |

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, a discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 230 West Street, New York, N. Y., for presentation by the Secretary or other representative of its staff. Unless special arrangement is made, the discussion of this paper will close Dec. 1, 1913. Any discussion offered thereafter should preferably be in the form of a new paper for publication in the next volume. (with suitable cross references in both volumes).

## The Critical Ranges A<sub>2</sub> and A<sub>3</sub> of Pure Iron.

K. BURGESS AND J. J. CROWE, BUREAU OF STANDARDS, WASHINGTON, D. C.

(New York Meeting, October, 1913.)

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THE question of the allotropy of iron, in spite of a vast amount of experimental work and perhaps an even greater amount of theorizing, is not yet settled. That there is a definite transformation in iron near  $900^{\circ}$  the A3 point, is generally recognized, as well as the fact that the temperature of this transformation is lowered by the addition of carbon and metallic elements. On heating, the transformation Ac3 is always found at a higher temperature than the transformation on cooling, Ar3. Whether the A3 transformation is sharp like the melting point of a pure substance, or extends over a considerable range of temperatures, embracing perhaps as a lower limit the A2 change, appears to be still an open question for pure iron. The nature and identity of the A2 transformation, it would appear from recent publications, has not yet been satisfactorily settled.

In the present paper a critical, historical summary is given of the experimental investigations of the location of A2 and A3 in pure iron, together with brief mention of some of the theoretical aspects of the subject, and an account is given of a series of experiments carried out with several samples of very pure iron which were studied by two methods of thermal analysis in the range from  $500^{\circ}$  C. to  $1,000^{\circ}$  C., and which it is believed furnish a contribution of considerable interest as to the location and nature of the A3 and A2 transformations.

Great attention has been given to the details of experimental manipulation and to the preparation of the samples, as it was soon found that some of the discrepancies noted in the work of many experimenters may be traced largely to lack of precautions which we have found essential.

For example, to anticipate somewhat, it is necessary to provide a suitable practically gas-free furnace, the heating and cooling of which may be regulated to a nicety. To render a minimum the deforming effects on the cooling and heating curves of the poor conduction of the sample, it must be of a form and mass to pass on its heat rapidly and completely to the thermocouple; and finally the sample itself must be freed from gases which, if present, further mask the definiteness of the heating and cooling curves. We have also varied within wide limits the several factors which may influence the determination of the exact location and shape of the transformation ranges, especially the mass and preparation of sample, rate of heating and cooling, design of furnace; and finally, as nearly as it is experimentally possible, we have worked with a substance approaching pure iron, free from occluded gases and other impurities, and contained within a vacuum.

liminary notice of some of the experiments carried out in 1912 has already been published,<sup>1</sup> but since this work the experimental method has been greatly improved and several newly prepared samples have been studied.

The methods of this investigation are described in detail, as they are the same now being used in a new study of the iron-carbon system, and because they are believed to be of some interest in themselves.

### THEORIES OF THE ALLOTROPY OF IRON.

Several explanations have been offered for the existence and nature of the transformations in iron, and the discussion of this subject has been linked with the transformations occurring in the iron-carbon system. For the consideration of *pure* iron, however, it seems unnecessary and sufficient to forget for the moment the iron-carbon system, which has no more relation to pure iron than, say, the iron-nickel or the iron-sulphur series of alloys. Furthermore, if there is no agreement as to the facts concerning these transformations, the establishment of a satisfactory explanation in terms of well-established physico-chemical principles should not be difficult. But without the presence of a double uncertainty, both as to facts and as to theory. Until the facts are well established and recognized, any explanation can be at best only a working hypothesis.

As has been stated, the current hypotheses regarding the A3 and A2 transformations in iron are:

The critical points A3 and A2 divide iron sharply into three allotropic forms:  $\gamma$  iron, above A3;  $\beta$  iron, between A3 and A2;  $\alpha$  iron, below A2.

The critical point A3 is the seat of an allotropic change, but the critical point is not, the transformation at A2 being associated mainly with the loss of magnetism, which is accompanied by a small thermal effect.

Hence, there is no  $\beta$  iron according to this theory, and the transformation may be abrupt or spread over a considerable temperature interval, as experiment may require.

The critical range A2 is not independent of A3 but forms a part of the A3 transformation. Here, again, we have no  $\beta$  iron, but the transformation for an evolution of heat on cooling at A2 requires assumption of the mutual solubility of  $\gamma$  iron in  $\alpha$  iron, and even the simultaneous existence is metastable equilibrium of two kinds of allotropic forms of the same substance.

<sup>1</sup> *Journal of the Iron and Steel Institute*, vol. lxxxvii. (1913, I), p. 335; *Journal of the Royal Academy of Sciences*, vol. iii., p. 329 (1913.)

This last type of physico-chemical equilibrium has been studied both theoretically and experimentally by Smits for several chemical systems, and for any particular case may be verified by noting the change in location of the transformation temperatures with rate of cooling.

Benedicks has put forth a theory of allotropy in which the allotropic change may be of several types, as illustrated in Fig. 1. To iron he would assign Type IIa, which relegates A2 to the end point of A3 or the temperature at which  $\gamma$  and  $\alpha$  irons cease to interact.

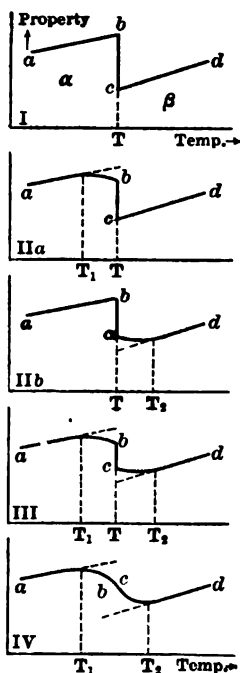


FIG. 1.—TYPES OF ALLO-  
TROPY, BENEDICKS.

If A2 can be shown to be constant in position independently of rate of cooling, then Smits's analysis will not apply, and if A2 persists in magnitude and location for heating and cooling through the A2 range and holding the sample a long time below A3 but above A2, Benedicks's hypothesis becomes of little meaning.

There are various other minor modifications of the above three hypotheses, all of which have been useful, and perhaps none of which is without value in furnishing some part of a satisfactory explanation of the transformations in iron.

#### PREVIOUS DETERMINATIONS OF A2 AND A3 IN IRON.

We shall pass in review briefly the experimental evidence as to the existence and nature of transformations in iron at A2 and A3 as shown from observations on the physical properties of iron, including dilatation, electrical and magnetic changes, specific heat, evolution and absorption of heat, crystalline structure, and deformation under stress. As we are dealing

with a single element, purely chemical changes would not be expected to shed any light on the question of such transformations, and there appear to be no strictly chemical data bearing on the subject, except some inconclusive work on the dissolving power for carbon.

In quoting the numerical values of the temperatures assigned to transformations as noted by the several observers (See Tables I and II), it should be borne in mind that there are considerable discrepancies in the temperature scales used, and sometimes the method of



ental operation leads to incorrect temperatures of the phenomenon measured. No general attempt is made here to correct the values as given by the several observers, as for the most part correction would be extremely uncertain. This uncertainty is enhanced in some cases by the impurity of the samples of iron used upon.

In this historical summary, we are more concerned with the quality of the transformations—their very existence, in fact—than with their exact location, which latter we believe is most exactly determined by our own experiments.

*Ranges as Determined by Expansion.*—Both from the work of G. Grenet and of Broniewski, observations on the expansion of iron give no indication of the existence of A2. The former place the transformation observed as lying in the interval from  $860^{\circ}$  to  $890^{\circ}$  for iron with 0.03 carbon, while the latter finds it above  $950^{\circ}$  for pure iron.

The disagreement here is great enough to again raise the questions done by Le Chatelier in 1899, of the speed and other conditions of heating, and also whether the sensibility of the methods used is great enough to detect A2. Even its non-existence, in so far as expansion is concerned, would prove only that iron immediately above and below A2 has the same coefficient of expansion, or that the A2 transformation is unaccompanied by appreciable change in volume, a not unreasonable possibility. The more recent observations of Rosenhain and Humfrey would appear to indicate a volume change accompanying A2.

*Ranges by Thermoelectric Observations.*—This method of observation is open to the serious objection for the exact location and determination of critical ranges, that the iron which forms one element of the thermocouple must be partly in a hot region and partly in a cold region. Transformations due to whatever transformations take place will be produced along the iron, and thereby may mask any transformation occurring, for example, after the one taking place at the lowest temperature.

With a Fe-Cu thermocouple, Broniewski finds for electrolytic iron a defined point of inflexion at  $730^{\circ}$  and another at  $950^{\circ}$  on the curve (or at  $850^{\circ}$  for 0.07 per cent. carbon), but with a Fe-Pt thermocouple is able to detect only the point at  $1,020^{\circ}$ , which Müller attributes to hydrogen. Both Harrison and Belloc fail to get any electric discontinuity with Fe against either Cu (Harrison) or Pt (Belloc), but appear to find a maximum for the curve of thermoelectric power at about  $800^{\circ}$ .

Thus the thermoelectric data on the critical ranges of iron appear to be meager and of little value, and the thermoelectric method cannot register transformations sharply except with an indefinitely short furnace, or one having no appreciable length between the inside and outside temperatures along the iron sample.

*Critical Ranges in Terms of Crystalline Structure.*—There appears to be practical unanimity of opinion concerning the evidence offered by the various investigations (Osmond and with Cartaud, Stead and Carpenter, Rosenhain and Humfrey, and others) concerning the existence of changes of crystalline structure: namely, that the change occurring in the A2 region is not accompanied by any appreciable crystalline change, while the A3 transformation in pure iron is so accompanied. All these experiments appear to show there is no crystallographic difference between  $\beta$  and  $\alpha$  iron, although there does not appear as yet to be perfect accord as to the nature of the crystalline change taking place at A3.

*Critical Ranges as Detected by Mechanical Methods.*—The study of the mechanical properties of metals at high temperatures offers very great experimental difficulties, and, as far as approximately pure iron is concerned, the only experiments which shed any light on the detection of A2 and A3 by mechanical means are those of Rosenhain and Humfrey, who have carried out two series of measurements on tensile strengths, the first of a more qualitative nature, in which an iron 99.76 pure, containing 0.03 carbon, was used, and the second, much more elaborate, with iron containing 0.1 per cent. carbon. Both series show a distinct discontinuity for the A2 range and for the A3 range. See Fig. 2.

*Critical Ranges as Given by Electrical Resistance.*—The electrical resistance of approximately pure iron at high temperatures has been studied among others by Le Chatelier, Hopkinson, Morris, Boudouard, Harrison, A. R. Meyer, and Broniewski.

The observations show, when plotted as resistance (or ratio of resistance hot to resistance cold,  $R_1/R_{20}$ ) against temperature, a continuous curve which begins to inflect at temperatures ranging from 700° (A. R. Meyer) to 800° or higher (Le Chatelier, Hopkinson). At about 900° to 950° the curve becomes nearly horizontal for all observers, and according to Broniewski has another inflection at 1,020°. This observer, however, took observations with the iron in an atmosphere of hydrogen, but Müller has shown that with electrolytic iron a critical point is obtained thermally in this region only until the hydrogen is removed by successive heatings.

The observations of Meyer appear to have been taken with consid-

re on very pure samples of iron, and when plotted as  $dR/dt$  give a cusp at  $700^\circ$  and are strikingly similar to the magnetic susceptibility curves as ascertained by Curie and others, as Fig. 2. The observations of Morris, who used iron 99.92, give a sharp maximum for  $dR/dt$  at  $765^\circ$ , and Somerville gets a maximum at  $750^\circ$  with an undefined iron, while Boudouard finds two maxima in the  $R : t$  curve, one at  $775^\circ$ , the other at  $885^\circ$ .

In the case of nickel with its single transition point in the range about  $370^\circ$ , the electrical resistance curve appears to antici-

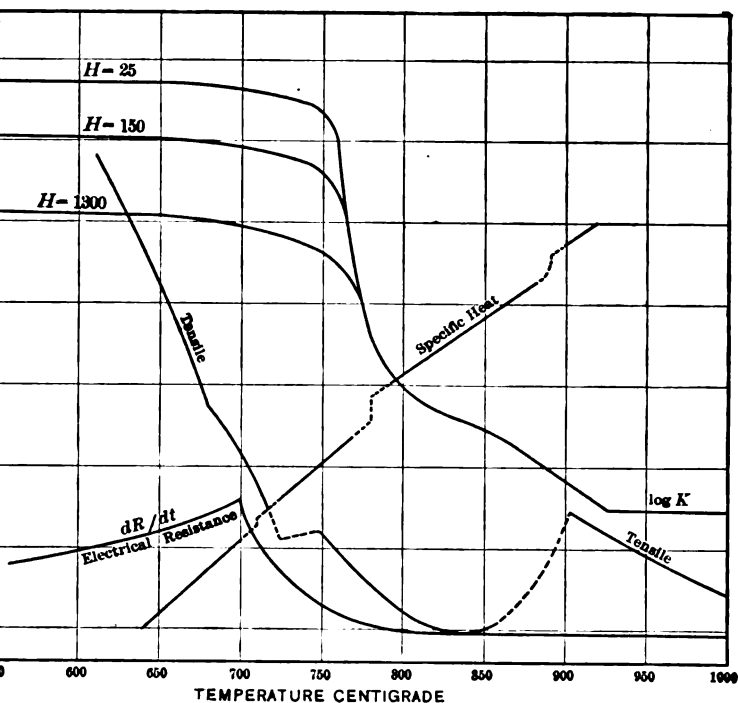


FIG. 2.—PHYSICAL PROPERTIES OF PURE IRON.

were, the A2 transformation for iron, which, as measured phenomenon, may be considered as starting some  $60^\circ$  or  $70^\circ$  below the maximum; or, in Benedicks's nomenclature, is a transformation of Type IIa. The observations of Broniewski also show a deflection (for A3?) at about  $950^\circ$ , although, if present, this should have been detected by Morris, Meyer, and others.

**Ranges as Determined Magnetically.**—Hopkinson, using iron containing 0.01 per cent. of carbon and 0.362 per cent. of impurities, mostly slag, finds a cusp in the permeability curve

at 775°, the permeability for a magnetizing force of 0.3 falling from 11,000 at 775° to 1 at 785°. With a mild steel containing 0.126 per cent. carbon and 0.244 manganese, the peak is at 780° for the same small magnetizing force.

The exhaustive experiments of P. Curie show that the intensity of magnetization ( $I$ ) is markedly dependent upon the value of the magnetizing force ( $H$ ) for iron containing only 0.04 per cent. carbon, and decreases (for all values of  $H$ ) at first gradually with rise in temperature and above 700° with increasing rapidity, reaching almost to zero at 750°, for all values of  $H$ , where there is an abrupt turn in the  $I$ : $T$  curve. Above 750°, the  $I$ : $T$  curve possesses no considerable variations until 1,280° C. The magnetic susceptibility  $k = I/H$  (plotted as  $\log k : T$  in Fig. 2) decreases with great abruptness at about 750°, although the decrease in  $k$  begins gradually from below 625° (high values of  $H$  decreasing  $k$  at lower temperatures than low values of  $H$ ). There is a further abrupt drop in  $k$  beginning at about 860° and terminating sharply at 920°. Terry finds that ferro-magnetism disappears on heating and reappears on cooling at 785°.

The magnetic behavior of iron in the region about 750° appears in all respects similar to the behavior of other ferro-magnetic substances, such as nickel, cobalt, and magnetite, in the region of their single magnetic transformation points, which for these substances, it is of importance to note, are also transformation regions as measured by other physical properties, such as electrical resistance, thermoelectricity, and thermal or calorimetric effects.

This last is well shown by the experiments of Weiss and his associates, who are able to compute from purely magnetic data obtained from higher temperatures the transformation points by means of the equation  $k(T - \theta) = \text{constant}$ , and compare them with the values obtained calorimetrically. In this way Weiss and Beck find: Transformation points  $= \theta - 273$ :

|                | Calculated<br>Magnetically. | Observed<br>Calorimetrically. |
|----------------|-----------------------------|-------------------------------|
| Iron.....      | 753°                        | 758°                          |
| Nickel.....    | 376°                        | 376°                          |
| Magnetite..... | 588°                        | 580°                          |

Later magnetic observations by Weiss and Foëx place the Curie point,  $\theta$  ( $= A_2$ ), at 774° for electrolytic iron using less than 0.5 g., divide the  $\bar{\beta}$  region into two parts,  $\beta_1$  and  $\beta_2$ , and locate the transition from  $\beta_2$  to  $\gamma$  iron with great sharpness at 920°.

Magnetically speaking, therefore, it appears reasonable to claim that the critical range  $A_2$  for iron is strictly similar to the trans-

taking place generally in ferro-magnetic substances as they pass into the feebly magnetic state. In addition, the iron undergoes a further distinct magnetic modification accompanying the A3 transformation.

*Ranges as Determined Calorimetrically.*—There have been many determinations of the specific heat of iron at high temperatures, but for most of them, in the range from 700° to 950° the observations are not closely enough spaced to locate the critical ranges with definiteness.

Reynolds and Beck were able to identify the Curie point, computed from magnetic data, with an abrupt change in the specific heat of iron about 755° to 760° (or A2), but did not go high enough in temperatures to reach A3.

Reynolds, using the vacuum furnace and calorimeter of Oberhoffer, was able to locate both A2 and A3 with considerable exactness in iron containing 0.06 per cent. carbon, in terms of the specific heat. He places A2 at 770° to 790° and A3 at 880° to 900°. The specific heat remains constant in temperature to the point O in Fig. 3. His calorimetric data, therefore, give positive evidence of the existence of A2 for iron containing about 0.06 carbon.

From Meuthen's calorimetric observations, the amount of heat effect at Ar2 is about the same as at Ar3, while by cooling-curve observations all observers find the heat effect at A3 at least three times that at A2.

*Ranges of Iron from Heating and Cooling Curves.*—An enormous amount of work has been done on the location by thermal analysis of the critical ranges of steels and other ferrous alloys, much of which is very contradictory. This is discussed at length in several papers and especially in a recent one by Prof. H. M. Howe.<sup>2</sup> While it may perhaps be thrown on the position and properties of A3 in iron from an examination of the behavior of impure irons, the A2 transformation in pure iron we would expect to learn little from a study of impure iron on account of the very small amount of heat involved in the transformation, which one would expect to be considerably masked or attenuated by the impurities.

It appears to be a remarkable fact, however, that, generally speaking, whenever A2 is detected at all, it is always found at the same temperature, whatever the composition of the iron alloy. For example, the discussion of Professor Howe would place the break at O

<sup>2</sup> Howe: Discussion of the Existing Data as to the Position of Ae3. *Bulletin of the American Iron and Steel Institute*, 1913, pp. 1099 to 1136.

in the line  $GOS$ , Fig. 3, at  $769^{\circ}\text{C}$ ., which is exactly the temperature we find experimentally for A2 max. in pure iron. In other words, the A2 line for the Fe-C system is horizontal, as shown from a discussion of practically all existing data, and the A2 point, viewed in this way, would appear to have the characteristics of a Fe-C eutectoid with the possible important if not crucial exception, of which we do not appear as yet to have sufficient experimental proof, that the quantity of heat involved in the A2 transformation does not vary appreciably with the carbon content from zero to 0.48 per cent. This constancy of heat of transformation together with its constancy in temperature, if both be definitely proved by using a pure Fe-C system, lend force to the idea that A2 is a transformation independent of the carbon present, and from the work of Moore and others, A2 appears to be independent of metallic components.

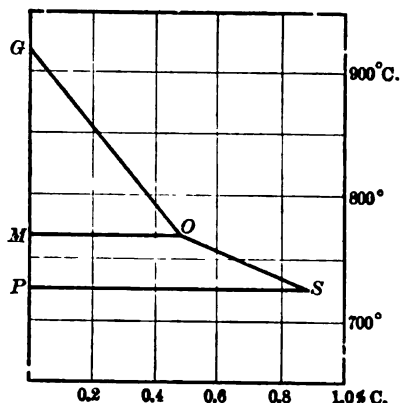


FIG. 3.—PART OF FE-C DIAGRAM.

As to A3, the comprehensive discussion by Professor Howe leads to an equilibrium temperature  $Ae_3$  of  $917^{\circ}$  for pure iron. This temperature,  $A_3 = 917^{\circ}$ , also satisfies the observations of practically all recently published work with very pure iron.

Returning to the A2 range in pure iron and its location by heating and cooling curves, we are confronted by considerable contradictory evidence as to its existence, location and type, whether possessing one or two cusps. Professor Benedicks<sup>3</sup> discusses the evidence given by the thermal experiments of Osmond, Roberts-Austen, Arnold and others and gives as well a concise critical summary of the whole subject of the nature of A2 in pure iron as shown by experiment, and concludes that A2 is not an independent transition point but forms a

<sup>3</sup> C. Benedicks: On Allotropy in General and that of Iron in Particular. *Journal of the Iron and Steel Institute*, vol. lxxxvi (1912, II), p. 242.

ling off, of A3, which latter is taken as a transformation of (see Fig. 1), and "According to this, the nature of  $\beta$  iron is on containing in solution a limited amount, increasing with  $\gamma$  iron."

Benedicks's publication, we have the experiments of Car- which he would have taken as verifying Benedicks's (or theory; of Guillet and Portevin, who appear to find A2 s distinct transformations; and of Broniewski, whose results ruous.

consider the experiments of Carpenter more closely. His ons of 1904, taken in association with Mr. Keeling on iron g 0.01 per cent. carbon, showed Ar2 sharply defined at  $762^{\circ}$  at  $900^{\circ}$ . Carpenter's observations of 1913, using iron with cent. carbon or of a carbon purity hardly detectible in dif- from his iron of 1904, also show Ar2 as present but not efined and ranging from  $768^{\circ}$  to  $741^{\circ}$ , while Ac2 is not in learly detectible from his curves except as a swell. The erences in these two series appear to be, that in the earlier ed cylinders of iron  $\frac{3}{8}$  by  $\frac{3}{8}$  in. were used, while in the later electrolytic iron 0.01 in. in thickness were rolled into a veighing 42 g. The curves differ in the main as one would ne poorer conductivity and the presence of gases in the sheets of otherwise untreated electrolytic iron producing a out, distortion, and displacement of the critical regions, of the feebler A2.

experimenters, notably Arnold, insist that A2 has a double pure iron, while it would appear from the work of several otably Carpenter and also Rosenhain, that A2 is erratic, sometimes double and sometimes single.

ering all the hitherto available data, there can be hardly any at, thermally, there is a critical range for pure iron in the hood of  $770^{\circ}$  (A2); but whether this be separate from the itical range near  $900^{\circ}$  (A3) and whether it (A2) be single or asped, the existing thermal observations do not prove con- but a fair inference would be that A2 is single and in- t of A3.

*Summary of Previous Determinations of A3 and A2 in Pure Iron.*—

for the moment, considering any theory concerning the of the transformations in pure iron, let us consider what is nt experimental basis for the existence of A2 and A3 either te or associated transformations.

mary of most of the experiments that have been made is

given in Tables I and II; the former includes only heating and cooling curve methods and the latter all others. These tables, taken in connection with the preceding paragraphs, show that there is overwhelming evidence for a discontinuity in properties of pure iron for the intervals of temperature roughly defined as 700° to 780° and 850° to 950°, or corresponding to the critical ranges A2 and A3. (See also Fig. 2.)

TABLE I.—*Thermal Maxima of Critical Ranges of Pure Iron by Various Observers.*

| Observer.                                          | Date.        | Carbon Content.             | Iron Content by Difference. | Ac2.         | Ar2.          | Ac3.          | Ar3.          | Remarks.                                                         |
|----------------------------------------------------|--------------|-----------------------------|-----------------------------|--------------|---------------|---------------|---------------|------------------------------------------------------------------|
|                                                    |              | Per Cent.                   | Per Cent.                   |              |               |               |               |                                                                  |
| Osmond.....                                        | 1887         |                             |                             |              | 750           |               | 890           | { Ar3 corrected from 855. Two max. for Ar2.                      |
| Roberts-Austen.....                                | 1891         | 0.007                       |                             |              | *             |               | 896           |                                                                  |
| Arnold.....                                        | 1894         | 0.008                       | 99.967                      |              | 750           |               | 854           | Ar2 is double.                                                   |
| Charpy.....                                        | 1896         | { 0.007                     |                             | 740          | 730           | 865           | 840           |                                                                  |
| Osmond.....                                        | 1899         | { 0.009                     |                             | 744          | 731           | 903           | 860           | {                                                                |
| Charpy and Grenet.....                             | 1903         | { tr.                       |                             | 800          | 780           | 906           | 880           |                                                                  |
| Carpenter and Keeling.....                         | 1904         | { 0.06                      |                             | 775          | 730           | 935           | 900           |                                                                  |
| Harkhort.....                                      | 1907         | { 0.01                      | 99.808                      | 755          | 780           | 885           | 880           |                                                                  |
|                                                    |              |                             | 99.89                       | 691          | 764           | 910           | 900           | {                                                                |
|                                                    |              |                             |                             | to 768       | to 759        | to 917        | to 875        |                                                                  |
| A. Müller.....                                     | 1909         | 0.017                       | 99.808                      | 770          | 768           | 917           | 894           | { 23 observations in vacuo, all agreeing very closely.           |
| Rosenbain and Humfrey...<br>E. Colver-Glauert..... | 1909<br>1910 | 0.029<br>Fe "Kahl-<br>baum" | 99.66                       | 770          | 763           | 941           | 904           |                                                                  |
| H. C. H. Carpenter.....                            | 1913         | 0.008                       | 99.967                      | ?            | 768<br>to 741 | 902<br>to 938 | 896<br>to 886 | { Ac2 not detected: 2 samples of same analysis; 10 observations. |
| Gillet and Portevin.....                           | 1913         | Not detected                | 99.66                       | { 791<br>788 | 778<br>778    | 987<br>982    | 912<br>902    |                                                                  |

The existence of A3 is not open to question, it having been readily located by practically all methods of physical analysis with the possible exception of electric resistance and thermoelectricity, for which any discontinuity is not very definite.

The magnetic change is also small but abrupt and unmistakable. The thermal observations, which give the sharpest definition of A3, show that the maximum of Ar3 is always lower in temperature than that of Ac3.

Controversy has raged warmly for a quarter century not only about the nature and extent but as to the very existence of A2, which has, however, been generally identified with the loss of ferro-magnetism in iron. The point of inflection of the electrical resistance curve appears to be associated with the A2 region, as well as an abrupt change in specific heat of the same magnitude as at A3. The thermo-



effect appears not less uncertain than at A3; there is a small abrupt change in tensile strength at A2; and there is a small effect on heating and cooling which appears to remain at a temperature for the addition of carbon or metallic considerable quantities. Apparently, the only phenomenon which has hitherto always given negative results for A2 is the structure.

TABLE II.—Critical Ranges in Pure Iron by other than Cooling-Curve Methods.

| Observer.       | Date.  | Carbon Content. | Iron Content by Difference. | A2.          | A3.                       | Method and Remarks.                             |
|-----------------|--------|-----------------|-----------------------------|--------------|---------------------------|-------------------------------------------------|
|                 |        | Per Cent.       | Per Cent.                   |              |                           |                                                 |
|                 | 1885   | 0.04            | 99.9+                       | 750          | 920                       | Magnetic.                                       |
|                 | 1897   | { 0.006         | 99.925                      | 765          |                           | Electrical resistance.                          |
|                 |        | { 0.010         |                             | 770 to 780   |                           | Magnetic.                                       |
|                 | 1889   | { 0.006         | 99.515                      | ?            | 880                       | Electrical resistance.                          |
|                 |        | { 0.010         | 99.128                      | 775          |                           | Magnetic, cusp — vs T curve.                    |
|                 | 1890   | 0.007           |                             | 780          |                           | Electrical resistance.                          |
|                 | 1899   | 0.057           | 99.763                      | ?            | 840                       | Expansion.                                      |
|                 | 1900   | Electrolytic    | ?                           | ?            | detected                  | Crystallographic.                               |
|                 | 1902   | ?               | ?                           | { Uncertain  |                           | Thermoelectric Cu-Fe couples, H atmos.          |
|                 | 1908   | "Pure iron"     |                             | 780 ?        | ?                         | Electrical resistance.                          |
|                 | 1908   | 0.03            |                             | ?            | 860 to 890                | Thermoelectric.                                 |
| Grenet.....     | 1903   | "Commercial"    |                             | 775          | 885                       | Expansion.                                      |
| Beck.....       | 1908   | ?               | ?                           | 760          |                           | Electrical resistance.                          |
|                 | 1909   | 0.029           | 99.767                      | detected     | detected                  | Calorimetric; A3 not measured.                  |
| and Humphrey... | { 1913 | 0.106           | 99.874                      | 750          | 910                       | Tensile and crystallographic, qualitative only. |
|                 | 1910   | 0.012           | 99.30                       | 785          | 910                       | Tensile strength.                               |
|                 | 1910   | 0.012           | "Iron"                      | 750          | ?                         | Magnetic.                                       |
|                 | 1911   | { 0.00          | 99.976                      | 700          | ?                         | Electrical resistance.                          |
|                 |        | { 0.00          | 99.94                       | 700          | ?                         | Fe "Kahlbaum." } Electrical                     |
|                 |        |                 | 99.85                       | 705          | ?                         | Ingot iron. } resistance,                       |
|                 |        |                 |                             |              |                           | Electrolytic. } cusp of                         |
|                 |        |                 |                             |              |                           | dR/dt curve.                                    |
| Ex.....         | 1911   | Electrolytic    |                             | 774          |                           | Magnetic; A3 not measured.                      |
|                 | 1912   | 0.06            | 99.960                      | 780          | 890                       | Calorimetric.                                   |
|                 | 1913   | { 0.07          | 99.87                       | 780          | 850                       | Thermoelectric.                                 |
|                 |        | { Elec trolytic |                             | 780 (a)      | 950                       | [couples.                                       |
|                 |        |                 |                             | { 750 to 780 | 950 and 1,020, 890 to 950 | (a) by Fe-Cu, (b) by Fe-Pt                      |
|                 |        |                 |                             | { 850 700?   |                           | Electrical resistance.                          |
| Arpenter.....   | { 1913 | 0.007           | 99.967                      | Not detected | Detected                  | Expansion.                                      |
|                 | 1918   |                 |                             |              |                           | Crystallographic.                               |
|                 |        |                 |                             |              |                           | Magnetic                                        |

although not all, of the phenomena appear to indicate that the transformation is abrupt at A3, in that for the latter the transformation is abrupt taking place at a higher temperature with ascending temperature and descending, while for the former the transformation is gradual (of Type IIa, Fig. 1), but has the same location of the transformation on heating and cooling. That A2 and A3 are parts of a transformation, A2 being subordinated to A3, is a conclusion

to be drawn with some difficulty from the data, and as pointed out by Guertler it is difficult to construct any plausible physico-chemical theory which would admit of a distinct heat evolution at A2 and still have A2 as a part of the A3 transformation, for "The end point is never marked by a sudden evolution of a new and constant thermal effect at a given temperature."

#### THE PRESENT EXPERIMENTAL INVESTIGATION.

The object of the present investigation is to determine, with several samples of pure iron of different sizes, prepared by various methods, the exact location and nature of the A2 and A3 ranges, using the most refined methods of thermal analysis and keeping the samples free from the masking influences of occluded gases.

*The Experimental Method.*—Two methods of taking heating and cooling curves have been used simultaneously on the same sample: one, the *inverse-rate* method of Osmond, in which the times required for the specimen to rise or fall successive, equal temperature intervals are noted in terms of the temperature or  $(dt/d\theta \text{ vs } \theta)$ ; the other, the *derived-differential* method of Rosenhain, in which the observations are taken by the *differential* method of Roberts-Austen using a "neutral" of platinum,<sup>4</sup> and in which for equal decrements or increments of temperature the difference in temperature between specimen and neutral is taken in terms of the temperature of the specimen  $(\theta - \theta' \text{ vs } \theta)/\Delta\theta = \text{constant}$ . The results so obtained by the differential method are transformed into the derived differential curve by the operation of dividing the differences,  $\theta - \theta'$ , for each temperature interval  $\Delta\theta$  by this interval and plotting in terms of  $\theta$ , or giving

$$d \frac{(\theta - \theta')}{d\theta} \text{ vs } \theta.$$

These two methods of thermal analysis supplement each other most excellently, as each is subject to different disturbing effects; and although obtained by totally different operations, the resulting heating or cooling curves are strictly similar except for certain minor details which we shall mention later. To operate both methods simultaneously requires no more apparatus or observers than the differential method alone, although in this latter case the chronograph may, less conveniently, be replaced by any sufficiently exact time-piece. It is preferable to have two observers, although this is not essential.

The inverse-rate method is subject to error due to drafts, sudden

<sup>4</sup> For a detailed description of the methods of taking cooling curves, see G. K. Burgess, Reprint 99, *Bulletin of the Bureau of Standards* (1909).

in current feeding the furnace, or any cause which may impose on the specimen thermal changes not proper to it. Inversion, at recalescence, or an actual increase in temperature on this is not readily expressible by other than a horizontal line in the plot; this weakness of analysis is of minor import, however, as the curves on which the inverse-rate curve is based give, nevertheless, fairly the beginning, maximum, end, and also, when present, the termination in temperature accompanying a transformation. This method, of course, only accompanies a violent evolution of heat and is of interest here.

The derived-differential method is less subject to error on account of extraneous influences; recalescence cannot be any more readily detected by this method of plotting than by the other. The presence of transition properties of a neutral free from transition ranges, as is platinum, has no appreciable effect on the location of the critical points in the plot, as in the case of iron under examination.

*Diagram of the Apparatus.*—The general appearance and arrangement of the apparatus is shown in Plate 1, and a schematic diagram, Fig. 4, gives the layout of connections.

*Measurement of Temperature.*—For this purpose, thermocouples were used and connected to a five-dial, low-resistance potentiometer designed to be free from thermal electromotive forces, of the Diessel type as constructed by Otto Wolff.

A moving-coil galvanometer (from Leeds & Northrup) used with the potentiometer had a constant sensibility for all parts of the range of the potentiometer as used, and gave when critically damped a deflection of 25 mm. on scale and telescope at 2 m. for each 20 microvolts of electromotive force of the thermocouple. As used, it had a resistance of 57 ohms and a period of 2 sec. This sensibility, which could have been increased if necessary. The zero shift was not troublesome and the instrument was glass inclosed, reducing exposure inequalities. The method of operation, whether for calibrating the inverse-rate or differential curves, was to note time, preferably with the chronograph, and this invariably when taking inverse-rate curves, every time the zero of the scale passed the cross hair of the telescope; the dial of the potentiometer was then turned say two divisions corresponding to about 2° C., throwing the zero of the scale about 25 mm., and the operation repeated indefinitely. The sensitivity is about 0.01° C. with the Pt-Rh thermocouples.

*Measurements of Time.*—For recording the time measurements, the chronograph was used for the inverse-rate method and convenient with the calibrating and differential methods, use was made of a cylindrical,

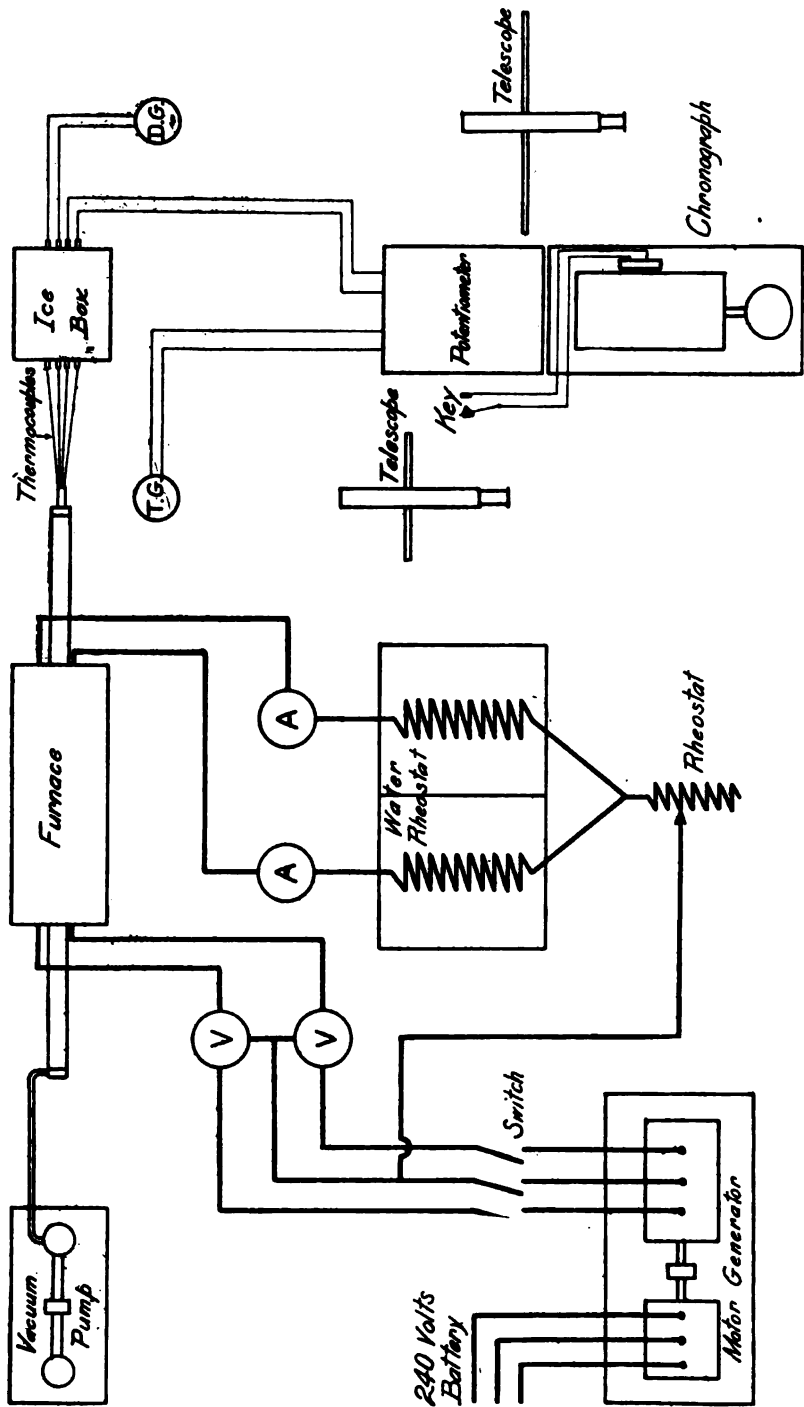


FIG. 4.—DIAGRAM OF APPARATUS.

motor-driven chronograph together with a telegraph key when depressed, gave a dash on the chronograph sheet easily shalshable from the seconds marks made on the same sheet with the pen when actuated through a relay by a standard clock situated in a distant constant-temperature room. The time observations were usually obtained to 0.1 sec.

*Thermocouples.*—In some of the preliminary work, various thermocouples of 0.6 mm. diameter were used, but the later more accurate measurements were all taken with three Heraeus 0.4 × 150 thermocouples of platinum, 90 platinum = 10 rhodium, marked M<sub>1</sub>, M<sub>2</sub>, and M<sub>3</sub>, and all cut off the same batch of wire. These were frequently interchanged during the investigation. A special thermocouple, M<sub>4</sub>, for measuring the difference in temperature between the iron sample and the platinum neutral, was made by joining a length of 45 mm. of 90 Pt—10 Ir wire between two pieces of platinum wire of the same grade as in the temperature-measuring couples. The cold-junctions of all thermocouples were kept at 0° C. in a suitable ice box, Fig. 4.

*Temperature Scale and Calibration of Thermocouples.*—The temperature scale used is that defined by the freezing points of the following metals:

|               | Degrees C. |
|---------------|------------|
| Zinc.....     | 419.3      |
| Antimony..... | 630.0      |
| Silver.....   | 960.0      |
| Copper.....   | 1,083.0    |

The calibration of the thermocouples was carried out as follows: The metals were melted in crucibles 14 cm. deep of Acheson graphite, about 300 cc. capacity in a Heraeus electric-resistance furnace lined with platinum foil. The thermocouples, while immersed in the metal, were protected by out-glazed Berlin porcelain tubes of 10 mm. diameter. Both freezing and melting points were taken several times for a first calibration, and the couples were occasionally checked at the silver point during the progress of the investigation, and recalibrated at the close, when they showed no appreciable change. The couples (M<sub>1</sub>, M<sub>2</sub>, M<sub>3</sub>) satisfied the same formula between 400° and 1,100° and may be expressed as follows:

$$\text{EMF} = -313.8 + 8.259 t = 0.001666 t^2 \\ t_0 = 0.$$

The EMF is expressed in microvolts and  $t$  is temperature in degrees Celsius. All thermocouple wires were electrically annealed at 400° C. before using,

It is interesting to note the excellent behavior of these thermocouples in direct contact with iron. The fact that there was practically no oxidation of the iron, together with the fact that the metals were always in a dry vacuum of the order of 0.01 mm. of mercury, probably accounts for this constancy.

*Mounting of Thermocouples.*—One junction of the differential couple together with the hot-junction of the temperature-measuring couple was inserted in the iron specimen undergoing study and the other differential junction, which was about 4.5 cm. away, was inclosed within the neutral, a platinum cylinder weighing 98 g. The bare wires were in direct contact with the iron, and in fact when very small samples were used, as 0.7 g. of iron from Professor Carpenter, the iron was hammered on to the couples. The sketch, Fig. 4, gives an idea of the arrangement when small cylinders (from 10 to 30 g.) were used.

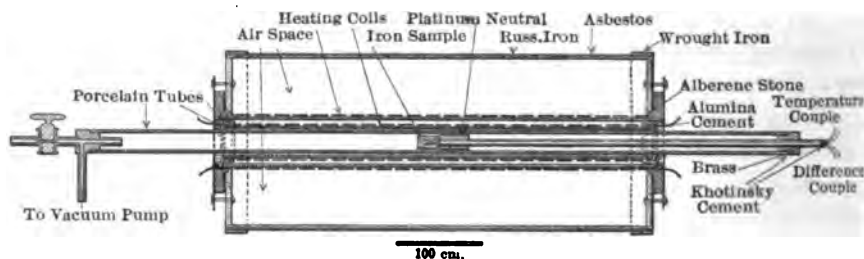


FIG. 5.—FURNACE.

*The Differential Measurements.*—The differential couple was connected directly to a Siemens & Halske moving-coil galvanometer of 200 ohms resistance. Deflections were read by means of a telescope and scale 2.5 m. distant. As connected, the galvanometer gave a deflection of 60 mm. for 100 microvolts, corresponding to a sensitiveness of nearly  $0.01^{\circ}$  C. with the Pt-Ir couple used. This was ample, and there would have been no advantage in increasing this sensitiveness, as could easily have been done fourfold by changing the galvanometer connections.

*The Furnace and Accessories.*—The furnace, shown in Fig. 5, was constructed in the laboratory, and consists essentially of four concentric tubes, three of Berlin porcelain and an outer one of iron backed with a  $\frac{1}{8}$ -in. layer of asbestos. The innermost tube, which carries the specimens under study, is glazed both inside and out, so as to hold a vacuum, and extends beyond the furnace to receive seals of hard wax and metal for pump and thermocouple. There was no trouble in holding a vacuum of 0.01 mm. of mercury to  $1,050^{\circ}$  C. The two unglazed porcelain tubes each carry a separate heating coil

platinum foil 2 cm. wide by 0.001 cm. thick. In some of the preliminary work a furnace was used in which a single heating coil was wound directly on the glazed tube carrying the specimen. This earlier arrangement is less satisfactory than the one above described, since the tube deteriorates sooner and the uniformity of temperature is less well maintained. As will be noted, the furnace is provided with no other insulation than these concentric tubes, thus permitting, when desired, the use of faster rates of cooling and reaching more conveniently lower temperatures than when the furnace is packed with insulating material.

With the construction described, there was no trouble whatever from drafts. The furnace was tested for freedom from critical ranges by taking several blank series of heating and cooling curve observations, using the usual platinum neutral and replacing the iron specimen with a cylinder of palladium. Some of these blanks are shown Plate VIII.

*The vacuum pump* used is a two-cylinder motor-driven Geryk pump kept in condition to maintain a vacuum of 0.01 mm. of mercury in the furnace as measured with a mercury gauge, and provided with drying tubes of phosphorus pentoxide.

*The energy supply* for heating the furnace was furnished by a 5-kw. Siemens-Schuckert motor-generator set delivering alternating current to the furnace and run from a 240-volt storage battery. Two of the three phases generated by the alternator were used at a voltage which could be set anywhere between 50 and 170 volts. This somewhat elaborate arrangement was found to be highly desirable when, as here, one is seeking minute thermal effects and every extraneous cause of variation in the rate of heating or cooling of the sample must be eliminated. There are two further advantages gained by using alternating current instead of direct for heating the furnace: it permits the use of a liquid rheostat without polarization or electrolysis and it eliminates any magnetic field about the iron sample. This last, if present, might conceivably influence the magnetic transformation in iron.

*The rheostat*, Fig. 6, deserves special mention, as it was specially designed to give automatically a constant rate of heating and cooling, variable at will within wide limits. In addition to wire rheostats a salt-water rheostat was placed in the heating circuit.

It consisted of a cypress box of two compartments, each measuring 35 by 35 cm., in each of which were two copper plates (35 by cm.), placed 30 cm. apart at the bottom and 1 cm. apart at the top. A metal box through which cold water was circulated for the purpose

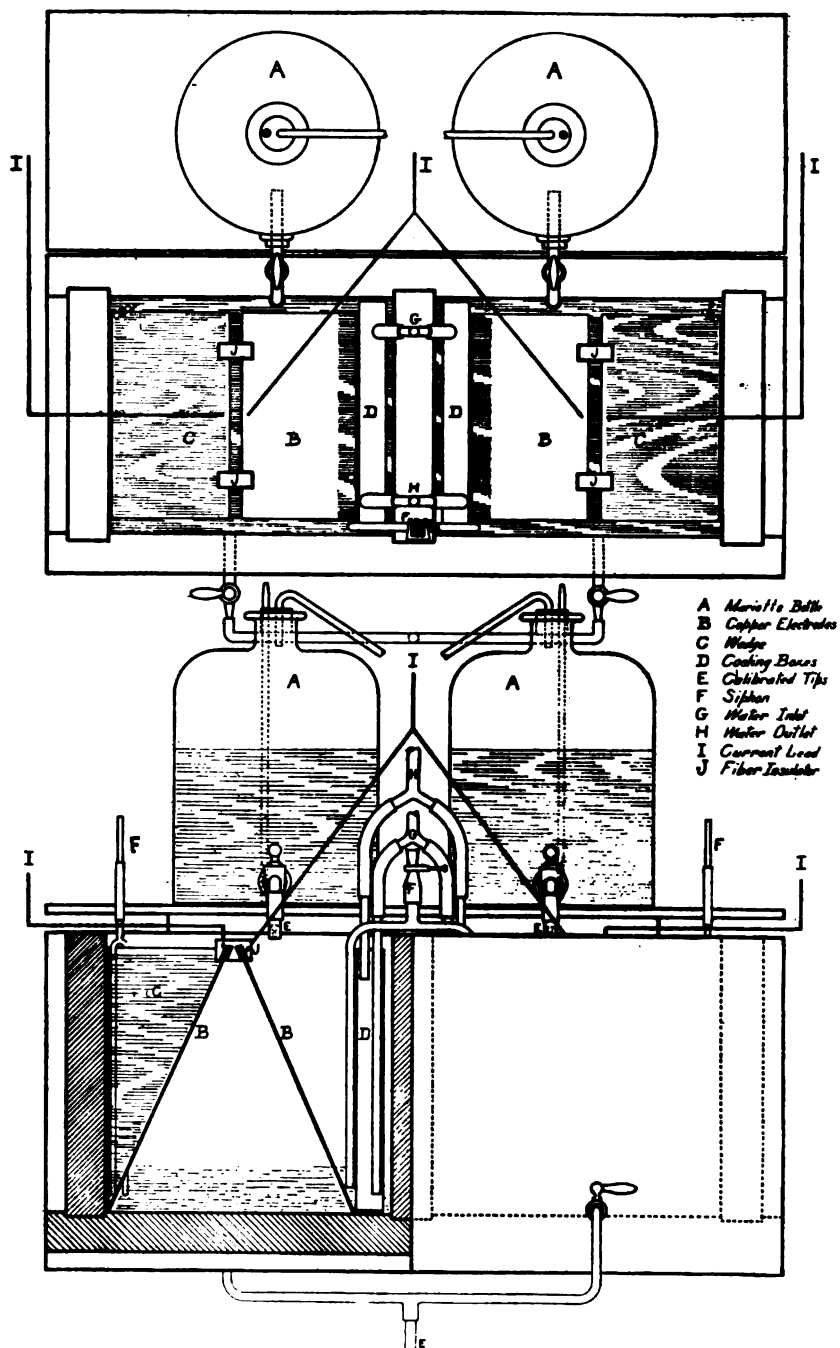


FIG. 6.—RHEOSTAT.



g the salt water cool was placed on each side of the partition. A side copper plate in each compartment, besides performing its duty as an electrode, also formed one side of a wedge which opened up and could be filled with water before starting a run. This was to cause the water which was fed at a constant rate from a bottle to rise between the copper plates at a faster rate as the temperature of the furnace increased, thus overcoming the greater losses to which the furnace is subjected at the higher temperatures and thereby giving a very constant rate over the whole range. In taking cooling curves the water in the wedges was kept at the same level as the water in the compartment by connecting them with a siphon; thus all the water was siphoned off at the same rate. A series of brass outlets were constructed and calibrated for use as a thermostat, which gave a series of definite times of heating or cooling the furnace, ranging from a few minutes to several hours.

#### THE MATERIALS INVESTIGATED.

*of Iron.*—It was considered worth while to examine the behavior of several samples of pure iron prepared by different methods and subjected to various preliminary treatments. We are indebted to Prof. C. F. Burgess, of Wisconsin, who furnished several samples of his electrolytic iron in the form of anode plates with thanks to Messrs. H. Goldschmidt and Cuntz, who furnished electrolytic plates and analysis of iron obtained from the German firm of Langheim-Pfanhauser; to Prof. H. C. H. Carpenter, of Manchester, New Hampshire, who kindly sent us some of the electrolytic iron he had used in his experiments on the critical ranges in pure iron, and which had been analyzed by Prof. J. E. Stead. Several samples of electrolytic iron were also prepared for this investigation at the National Bureau of Standards by Messrs. Cain and Cleaves, using a method to be described elsewhere. There is also included a sample of "cast iron," for which we are indebted to the American Rolling Iron Co. of Middletown, Ohio.

*Preparation and Description of Samples.*—The samples were prepared by heating and cooling curves by cleaning with alcohol and oil. In the case of the untreated electrolytic irons of C. F. Burgess and Langheim-Pfanhauser, the samples 1, 16, 17 and 26 a, in the form of plates, from  $\frac{1}{8}$  to  $\frac{1}{4}$  in. thick, were bored out to receive thermocouples. Some preliminary but less satisfactory measurements were made with small pieces packed about the thermocouples and within a thin-walled platinum cylinder of 3.5 cm. length and 1.5 cm. diameter. With this last arrangement, the

transition points were not always very sharply defined, due apparently to a progression of the reaction from one piece to another.

The first curve, and often several of the succeeding curves taken with untreated electrolytic plates which are known to be heavily charged with gas, especially hydrogen, was erratic, an effect due for the most part to the presence of these gases within the sample producing parasitic evolutions and absorptions of heat. See Plate XI. This gas effect has been noticed by other observers.

To obviate this troublesome effect, it was decided to melt some of the samples of iron before taking the heating and cooling curves, which melting was carried out successfully both in a vacuum electric furnace and in gas-fed furnaces. This melting of the iron, provided contamination from crucible or furnace atmosphere is avoided, has the great advantage of further purifying the iron by the removal of all or nearly all of the contained gases. Electrolytic iron, for example, bubbles very violently on first melting *in vacuo*, showing that a considerable quantity of gas remains occluded to the temperature of fusion and is only removed by melting the iron. Melting *in vacuo*, as is shown for samples 25 and 26 as compared with 1 and 26a, Table III, appears also to lower the already very small carbon content of the iron to almost nothing, again increasing the purity with respect to the most undesirable element, carbon. Finally, electrolytic iron, which has been melted either *in vacuo* or in gas furnaces, possesses a sharply defined heating curve the first time such iron is reheated, so that a very troublesome source of uncertainty is removed by this melting. That the presence of gases in the iron has a considerable effect on the location and range of the critical ranges is also shown in later paragraphs.

For all these reasons it appeared to us desirable, when making a thermal study of iron and its alloys which occlude or contain gases, to remove these gases by a previous melting of the metal, preferably *in vacuo*.

There was considerable range in mass from one sample to another used in taking heating and cooling curves, as shown in Tables IV and VI, or from 0.7 to 35 g. It is our experience that it is advantageous to work with as small samples as the precision of the experimental method will permit when it is desired to locate the exact temperatures of the critical ranges of the material. The apparent advantage to be gained with larger samples, which absorb or set free greater quantities of heat, appears to be more than offset by the conductivity of the larger sample not being sufficient to transmit promptly enough the heat generated to the thermometric device. If there is

uniformity of temperature throughout the sample, this effect is reduced; and a phenomenon which really takes place at a single temperature will then appear to be spread over a range of temperatures. We believe this spreading and attenuation of the reaction is a principal reason why Professor Carpenter was not able to detect it with certainty using 42 g. of metal in the form of a thin sheet heated to a cylinder, while with only 0.7 g. of his iron we were able to heat AC2 with great sharpness. (See Plate VI.)

For melting *in vacuo*, the Arsem furnace was used, the iron being heated in a crucible of pure magnesia placed within a tube of hardt porcelain. For melting in the gas furnace, covered clay crucibles brasqued with pure fused magnesia were used.

TABLE III.—Description and Chemical Analyses of Pure Iron.

| Description.                          | Analysis Furnished by | No. | C.                        | S.                     | P.           | Si.             | Mn.           | Cu.     | Fe by Difference. |
|---------------------------------------|-----------------------|-----|---------------------------|------------------------|--------------|-----------------|---------------|---------|-------------------|
| Carbide Electrolytic 0.01-in. sheet.  | Stead                 | F5  | 0.008                     | Tr.                    | 0.002        | 0.014           | 0.009         |         | 99.967            |
| Ingots remelted in gas furnace        | Bur. Stds.            | F1  | 0.012                     | 0.020                  | 0.001        | 0.008           | 0.029         | 0.06    | 99.905            |
| Electrolytic remelted in gas furnace  | Bur. Stds.            | F2  | { 0.008<br>0.009          | { 0.045<br>0.043       | Tr.          | 0.004           | Tr.           | > 0.001 | 99.941            |
| Electrolytic remelted in gas furnace  | Bur. Stds.            | F3  | 0.007                     | 0.011                  | > 0.001      | 0.004           | Tr.           |         | 99.977            |
| Electrolytic remelted in gas furnace  | Bur. Stds.            | F4  | 0.009                     | { 0.010<br>0.009       | > 0.001      | 0.006           | Tr.           | 0.006   | 99.968            |
| Electrolytic remelted in gas furnace  | Bur. Stds.            | F6  | { 0.019<br>0.013<br>0.015 | > 0.001<br>by solution | Tr.          | 0.007           | Tr.           | > 0.001 | 99.975            |
| Electrolytic remelted in gas furnace  | Bur. Stds.            | F7  | { 0.014<br>First          | > 0.001<br>burning     | Tr.<br>0.008 | 0.008<br>second | Tr.<br>0.006C | > 0.001 | 99.971            |
| Electrolytic remelted in <i>vacuo</i> | Bur. Stds.            | 25  | 0.003                     | 0.006                  | 0.004        | 0.004           | 0.000         |         | 99.983            |
| Electrolytic remelted in <i>vacuo</i> | Bur. Stds.            | 26  | 0.001                     | 0.004                  | 0.006        | 0.007           | 0.000         |         | 99.982            |
| Electrolytic plates                   | Bur. Stds.            | 26a | 0.006                     | 0.004                  | 0.001        | 0.006           | Tr.           | 0.011   | 99.970            |
| H. Goldschmidt                        |                       |     | 0.00                      | 0.00                   | 0.007        | 0.00            | 0.00          | 0.006   | 99.98             |
| Electrolytic plates                   | Bur. Stds.            |     | 0.009                     | 0.003                  | 0.001        | 0.006           | Tr.           | 0.006   | 99.975            |
| C. F. Burgess                         |                       | 1   | 0.012                     | 0.00                   | 0.004        | 0.013           | 0.00          |         | 99.971            |

*Chemical Analyses.*—The chemical analyses of the different preparations of iron used are shown in Table III, including mention of who made the analyses. Those at the Bureau of Standards were made by Messrs. Cain, Cleaves, Tucker, and Witmer. In all cases the analyses were made of the metal in the condition stated in the column headed "Description," and the pieces for analysis were cut from the ingot or plate used for taking the heating and cooling curves. It is noted that the purest iron is 99.983 Fe, obtained by remelt-

ing electrolytic iron *in vacuo* in magnesia crucibles. The two samples remelted *in vacuo* are also the lowest in carbon content, 0.003 and 0.001 per cent., respectively. The average carbon content of all samples is 0.009, and the range, from 0.001 to 0.015. It is of interest to note that with the exception of the Mn and Cu contents, the "ingot iron" is nearly as pure as the average of the electrolytic irons.

Where there are check analyses by different chemists, and in the case of the carbon determinations by different methods, when one considers the difficulty of exact determination of such small quantities of impurity, the agreement is extremely satisfactory, and in most cases may well be within the degree of homogeneity of the samples. None of the samples was analyzed for oxides, but their amount, if present, must be very small.

#### THE EXPERIMENTAL DATA.

We have divided the data into two chronological portions:

(1) A preliminary series of observations carried out with a furnace and rheostat of somewhat less satisfactory form than that of Figs. 5 and 6, with less precaution for holding a good vacuum and steady current, and in part with the iron samples in a less concentrated form; nor was the thermocouple calibration as carefully checked in all cases. These preliminary observations, although we do not place the reliance on all of them, for the exact location of temperatures, that we do on the definite series, are, nevertheless, quite instructive in showing some of the things that should be avoided in the exact thermal analysis of a substance occluding gases, and also furnish data for discussing the effects of varying some of the factors that influence the location of the critical ranges.

(2) The definite series of observations were then carried out with all the precautions and improvements in method and manipulation our preliminary measurements had shown to be necessary; it is on this definite series, together with the last two of the preliminary series, that we mainly base our conclusions regarding the allotropy of iron as shown by thermal analysis.

In all cases, attention should be given mainly to the location of the *maxima* of the critical ranges, as the beginnings and endings, especially the former on heating, are, in general, not to be located with exactness.

*The Preliminary Observations* have already been reported on briefly, but are here included in full for the sake of completeness. See Table IV. The numerical values here given are in some cases slightly different from those previously published, due to some of the indications of one of the thermocouples needing correction. Three Pt-Rh thermocouples, C<sub>1</sub>, W<sub>11</sub> and W<sub>12</sub>, were used in these preliminary observations.

[illegible]

All but one of the samples of iron are electrolytic: three from Prof. C. F. Burgess, Nos. 1, 16, 17; sample No. 25 remelted *in vacuo* is from the same lot as No. 17; and No. 26 is from the Langheim-Pfhanhauser A-G., also remelted *in vacuo*. The electrolytic plates were relatively thick, from  $\frac{1}{8}$  to nearly  $\frac{1}{4}$  in.

The mass of the samples ranged from 15 to 31 g., and for the first three series the iron sample consisted of more than one piece of metal. The first three, Nos. 1, 16, 17, were from the electrolyte plates deposited; Nos. 25 and 26 were remelted *in vacuo*, and No. 22 is ingot iron, remelted in a gas furnace, of similar quality as sample F1 of Table III.

Several facts stand out prominently from these preliminary observations. In the first place, in contrast to the samples remelted *in vacuo* before taking heating and cooling curves, which samples show the Ac2 and Ar2 maxima sharply defined at a single temperature, 768°, the untreated electrolytic samples show a wide and variable interval between the Ac2 and Ar2 maxima, an interval in some individual cases greater than 50°. With untreated electrolytic irons, Ac2 is always higher and Ar2 always lower than the single A2 point at 768° as found with the remelted irons. Again, the position of the maxima of Ac3 is higher and of Ar3 lower, with very considerable variations, for the untreated samples; or in other words the interval Ac3—Ar3 (maxima) is considerably less, from 10° to 14°, for the samples reheated *in vacuo* than for the untreated samples, for which this interval ranges from 20° to 40°.

These results show the important rôle played by the occluded gases, and an examination of the data of the tables shows that several reheatings to 1,050° *in vacuo* are not sufficient to put thick electrolytic iron plates into a satisfactory condition for making a thermal analysis of their critical ranges. When there are several pieces making up a sample (as Nos. 16 and 17) the retarding effect of poor conduction also enters somewhat.

Remelting appears from these observations to be an essential preliminary treatment to which the iron should be subjected unless several rates are used, as we shall show below. We desire to emphasize this point, for we believe that one of the main reasons why many of the previously published results with electrolytic iron show inconsistencies and variations in the location of A2 and A3, is due to the fact that the gases have never been sufficiently removed, or the samples were not in a compact enough form, or both effects superposed, and sometimes associated with a too wide temperature interval between observations.

property that appears to be common to all these samples is that, on average, for A3 the *beginning* of Ac3 is at the same temperature as the *beginning* of Ar3, within the limit of accuracy with which somewhat indefinitely defined temperatures can be located. This characteristic sharply distinguishes A3 from A2; for the latter, as we have seen, the maxima of Ar2 and Ac2 coincide when the samples are compact and gas-free.

As to the effect of rate of heating or cooling upon the location of the critical ranges, it will be noted, Table IV, that for the rates here used,  $0.6^\circ$  to  $0.35^\circ$  per second (or 17 to 3 sec. per degree), there is no effect on the location of A2 (max.) for the samples 25 and 26 when heated *in vacuo*, or for sample 22, ingot iron remelted in gas furnace. For the untreated samples a fast rate accompanies a greater effect in Ac2-Ar2. For the A3 range the effect of rate is less marked for the untreated samples but appears to be appreciable for the premelted samples. Table V shows that reducing the rate gives  $769^\circ$  for A2 (= Ac2 = Ar2) for all samples; and for A3 and for zero rate Ac3 - Ar3 =  $12^\circ$ , with Ac3 =  $912^\circ$  and Ar3 =  $900^\circ$  on the average.

TABLE V.—*Maxima of Critical Ranges for Zero Rate.*  
*Preliminary Series.*

| Ac3. | Ar3. | Ac3-Ar3. | Ac2. | Ar2. | Ac2-Ar2. |
|------|------|----------|------|------|----------|
| 914  | 900  | 14       | 768  | 767  | 1        |
| 913  | 900  | 13       | 769  | 769  | 0        |
| 911  | 896  | 15       | 770  | 769  | 1        |
| 909  | 895  | 14       | 769  | 772  | -3       |
| 912  | 903  | 9        | 769  | 769  | 0        |
| 913  | 909  | 4        | 768  | 768  | 0        |
| 912  | 900  | 12       | 769  | 769  | 0        |

It therefore appears that in spite of the wide variations noted in Table V, the nature of the sample, whether or not gas-free or not, and whether in one or several pieces, does not influence the location of the maxima of the critical ranges when reduced to zero rate of heating or cooling.

The *Definite Series of Observations* is shown in Table VI, in which are included all the observations taken with the improved apparatus Nos. 4, 5, and 6 on the samples here included. There are three samples of electrolytic iron prepared by J. R. Cain, F2, F', F7; one electrolytic sample, F3, prepared by Langheim-Pfanhauser; and one, F4, from Prof. C. F. Burgess; and one of ingot iron, F1, all of which were remelted in a gas furnace before taking observations. Samples F8 and F9 are small samples from Nos. 25 and 26 respectively of the preliminary series; and F5 is a piece from an electrolytic sample which had been studied thermally by Professor J. R. Cain.





Considering first the existence and location of the maxima of the series, the observations on all these nine samples show most emphatically the existence of a common maximum for Ac2 and Ar2 at the rate of  $1^\circ$  among the samples and as between the Ar2 maxima. This result is identical with that found for samples Nos. 25 and 26, reheated *in vacuo*, of the preliminary series and for the others of this series when reduced to zero rate. The constancy of (maximum of)  $\text{Ac2} = \text{Ar2} = 768^\circ \text{C.} \pm 0.5$  is seen to persist for variations in mass from 0.7 to 35 g., in rate of heating or cooling from  $0.05^\circ$  to  $0.35^\circ$  per second, for iron remelted in either a gas furnace, whether of electrolytic or "ingot" preparation, as determined in two differently constructed furnaces in which five separately calibrated thermocouples by two methods of analysis.

A small, electrolytic sample, F5, from Professor Carpenter, which had been heated by him six times to  $1,000^\circ \text{C.}$ , also behaves like the others.

Coming now to the maxima of A3, we see that for all the samples located at  $912^\circ \pm 2$ , while the agreement for Ar3 is apparently so good, the range being from  $880^\circ$  to  $903^\circ$  for the different samples and the mean value of Ar3 is  $889^\circ$ . It is to be noted that samples F8 and F9 preheated *in vacuo* are in agreement with Nos. 25 and 26 of the preliminary series, again showing the smallest inconsistency,  $\text{Ac3} - \text{Ar3} = 14^\circ$ .

In the preliminary series, the beginning of Ar3 is located, in fact, at about the same temperature as the beginning of Ac3, although these beginning temperatures are not defined with sufficient accuracy to warrant certainly the statement that the A3 transformations occur at the same temperature on heating and in cooling, but this appears highly probable.

The effect of rate of heating or cooling can be seen in the location of the critical range A2. For the critical range A3, when the observations on Ac3 and Ar3 are plotted in terms of rate of heating or cooling (see Fig. 7) the anomalies in location of Ar3 largely disappear although extrapolating Ac3 and Ar3 to zero rate again fails to give a single equilibrium temperature Ac3. For zero rate,  $\text{Ac3} = \text{Ar3} = 897^\circ$ , or there is apparently a real difference of some  $10^\circ$  in the location of the maxima of this transformation, or in exact agreement with the preliminary series.

Considering both series, it seems safe to say that we may place  $\text{Ac2} = \text{Ar2} = 768^\circ \pm 0.5$  and  $\text{Ac3} = \text{Ar3} = 897^\circ \pm 1$  and  $\text{Ar3} = 898^\circ \pm 2$  and  $\text{Ac2} = \text{Ar2} = 768^\circ \pm 0.5$  for iron passing through A3 and A2 at zero rate, and through

A2 at any rate provided the iron is gas-free, and in the form of a single compact piece.

#### DESCRIPTION OF THE PLOTTED CURVES.

An examination of the actual heating and cooling curves is also essential. For most of the samples both inverse-rate (Marked I), and derived-differential (marked D) heating and cooling curves are recorded. Observations were usually taken at  $2^\circ$  intervals, although others were sometimes used—i. e.,  $1^\circ$  and  $4^\circ$  steps—which are evident from inspection. For all curves the ordinates represent temperatures centigrade; for the inverse-rate curves the abscissæ represent time in seconds to change the temperature of the sample by the unit interval ( $1^\circ$ ,  $2^\circ$  or  $4^\circ$ ); and for the derived-differential curves the abscissæ represent deflections on the differential galvanometer scale expressed in millimeters.

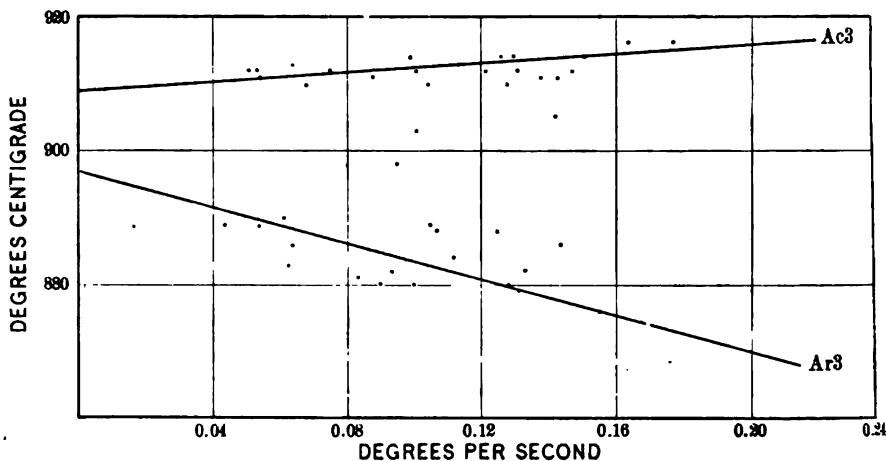


FIG. 7.—TEMPERATURE VS. RATE FOR A3 RANGE, DEFINITE SERIES. SAMPLES F2, F2', F3, F4, F5, F7, F1, F8, F9.

*The Effect of Plotting at Different Intervals* is shown in Plate III for the observations of a single heating and cooling curve of sample A1. It would appear that there is no advantage in reducing the interval at which temperatures are taken to as small as  $1^\circ$  in the desire not to miss any very slight transformation; on the contrary, the sensibility is thereby reduced proportionally, since what is measured is only the effect between two successive taps of the key. On the other hand, with wide intervals such as  $4^\circ$  missing a single observation may be sufficient to throw the whole series into doubt. The interval chosen,  $2^\circ$ , appears to avoid satisfactorily the two pitfalls of lack of sensibility and danger of missing the cusp of a transformation.

curves of the *Definite Series* are shown in Plates IV to VIII. A detailed study was made of sample F2, consisting of 33 g. of remelted electrolytic iron prepared by Mr. Cain. In contrast to observations by ourselves and others on untreated electrolytic iron which show irregular curves for the first three or four heatings, in remelted iron the first curve is about as regular and sharply defined as the succeeding ones. The similar character of the two curves is well shown here, the only considerable difference being that for very slow and for rapidly changing rates the inverse curve shows marked departures from the vertical. It is apparent from inspection of the curves that although the maxima and to a large extent the ends of the critical ranges are sharply defined, the determination of the beginnings, especially on heating, is attended with considerable uncertainty for both types of curve.

The curves of Plate IV<sub>A</sub> show the results of an effort to attenuate the A2 point, if possible by various operations, the A2 point. As the results indicate, it is impossible to influence the position or nature of the A2 point by any thermal operations performed upon the iron above this temperature. Thus during the sixth heating, the sample was held 71 min. at 825°, heated to above A3 and then cooled; on the seventh it was heated to just below the beginning of A3 and then cooled; in the eighth and ninth it was heated and cooled twice in the short range, including the A2 point; in the tenth it was held just below A3 and then carried up and down three times in the A3 range before cooling. In all these operations, Ac2 and Ar2 remain unchanged in any way, and the evidence is abundantly clear that the critical range A2 is in no sense related to the A3 range, as has been suggested it might be, particularly by the observations of F2.

A small piece (1.5 g. = F2') of the above sample was also heated with the same results (Plate IV).

Observations with several other samples of electrolytic iron, including F7, remelted in the gas furnace, are shown in Plates V, VI, VII, and VIII, corroborating the previous observations. It will be seen in each case the first heating gives as definite results as the succeeding ones. A sample of 35 g. of remelted ingot iron, F1 (1), gives the same type of curve as the remelted electrolytic iron.

A sample of particular interest is F5, it being 0.7 g. of Professor F. A. J.'s electrolytic iron, which is seen (Plate VI) to behave like the others, showing Ac2 and Ar2 both clearly located on the curves at 768°.

The advantage of using small samples for sharply defining the magnitude of the critical ranges is well shown for the curves of F5 (0.7 g.), F8 (1.0 g.), and F9 (2.1 g.), Plates VI and VII, the last two being pieces remelted *in vacuo*. These very small samples were also inclosed within the platinum neutral in the furnace, a proceeding which appears to be advantageous, since the sample F2' of 1.5 g. not so inclosed (Plate IV) shows the A3 range much less sharply.

*The Curves of the Preliminary Series* are not all presented here, but a sufficient number are included to indicate the constancy of behavior attained with the variously prepared samples with the unperfected apparatus and at times with an unsteady heating current. All the observations taken of one of the electrolytic samples premelted *in vacuo* (No. 26) are given and this series of curves (Plates X, XA, and XB) gives a fair example of them all. Some of the untreated electrolytic samples give somewhat erratic results, as shown for sample No. 1. Plate XI. The curves for the ingot iron, sample No. 22, Plates IX and IXA, are also representative of the results obtained with the earlier apparatus.

*The Existence of Other Critical Ranges.*—Several observers have announced the existence of transformation points in addition to A2 and A3, notably by Sir Roberts-Austen, who considered he had found several points below A2; by Carpenter, one at 675° which Rosenhain later attributed to the heating tube; by Arnold, a "fourth recalcrescence point" between A3 and A2 (or a doubling of A2); by Robin. two critical regions below A2 near 400° and 100° respectively; and by P. Curie, Broniewski, and others, one or more points above 1,000°.

A few of our observations extend to as low as 300° and as high as 1,050° without indicating the presence of any critical regions above A3 or below A2.

Some of the curves, particularly on cooling, give slight evidence of a minute transformation at about 805° (see in particular, several of the cooling curves for sample F2), although with the other samples this point can hardly be said to be present. If a point between A3 and A2 is really present, this would corroborate the magnetic observations both of Curie and of Weiss and Foëx, whose susceptibility curves show an inflection between A2 and A3 (see Fig. 2).

There is more positive evidence of a slight absorption of heat in the heating curves corresponding in temperature to the maximum of A3. Although not always present in the heating curves, this doubling of A3 is well shown, mainly for the inverse-rate curves, in the following of the definite series: Sample F7, both curves; the curves

of very slow rate of sample F2, especially the fifth; F4, all curves; F3, F1, and F8, slightly evident; while this doubling is apparently absent in F9 and F5 (Carpenter's sample), both of very small mass.

Some of the curves of the preliminary series also show one or another of these secondary points, (see Plates IXA and XB) usually more marked in the inverse-rate curves, but, due to the relative irregularity of the preliminary series, as compared with the definite series using the perfected apparatus, we do not place any considerable reliance on the former for this purpose.

In view of the apparent impossibility of finding experimentally a common equilibrium temperature  $Ac_3$  for the heating and cooling curves, the presence of an inferior, even if slight, transformation on heating at the temperature of  $Ar_3$  would be an aid in explaining this anomaly, although the allotropy of iron would thereby be further complicated,—a step we are by no means anxious to champion, unless the facts are considered sufficiently convincing.

#### MICROSCOPICAL EXAMINATION.

(By H. S. Rawdon.)

Figs. 1 and 8 of Plates II and IIA. which are micrographs of a sample of electrolytic iron prepared by J. R. Cain, Bureau of Standards, illustrate the appearance of the metal upon deposition. The iron is quite different in its properties from iron under ordinary conditions. It is quite brittle and hard, and the samples for microscopic examination are prepared with much less difficulty than after the iron has been melted. This difference is undoubtedly due to the hydrogen which saturates the metal as a result of its method of preparation.

All of the other specimens examined show some spherical gas bubbles, due to the liberation of the dissolved gases during the processes of melting, and which did not escape from the iron on account of its viscosity. These bubbles have a peculiar appearance under vertical illumination, resembling inclusions of  $MnS$ . This is due to the absence of all oxide film from the walls of the bubble. Fig. 5 shows this appearance of the bubbles somewhat. These bubbles occur in all the specimens regardless of their method of melting, and also very small ones in samples which were heated for the cooling-curve determination without previous melting. Fig. 3 of the photomicrographs is interesting in showing the interior veinings in the iron crystals which appear upon deep etching after considerable heating.

All of the photomicrographs, unless otherwise stated, are at a magnification of 100 diameters. Picric acid was used as an etching agent.

## SUMMARY AND CONCLUSIONS.

In the first part of this paper, after a brief statement of the current theories of the allotropy of iron, we have given what we hope will be considered an impartial account of the numerous experimental efforts of others to locate and define the critical ranges A2 and A3 of pure iron in terms of the various physical phenomena which have been found to change with temperature.

These observations are embodied in Tables I and II, from which it is seen that all the physical properties of iron which have been studied, with the single notable exception of crystallographic structure, have shown, in the hands of one or more skillful experimenters, a distinct discontinuity for the A2 range as well as for the A3 range. For several of the phenomena, such as electrical resistance, thermoelectricity, specific heat, and magnetism, it would appear that the discontinuity is at least as great for A2 as for A3, while the thermal effect has of course been long recognized as being much the more pronounced at A3.

The investigation proper consisted in taking *in vacuo* some 130 heating and cooling curves by two methods simultaneously, the inverse-rate and differential, for 15 samples of pure iron prepared by various methods and analyzed by several chemists. Unusual precautions were taken to secure uniformity of heating of the samples, and it was also possible to take observations for samples of widely different mass and over a wide range of rates, each maintained strictly constant. Two furnaces were used, and temperatures were taken with six separately calibrated thermocouples. The observations show that in order to get consistent and reliable results in the thermal analysis of a substance such as iron, the properties of which are so readily susceptible to many minor influences, it is necessary to get rid of all the disturbing influences.

We find essential the following precautions:

1. The iron should be pure; our purest samples were 99.983 and contained 0.003 per cent. carbon or less; and it should be kept pure by heating it only *in vacuo*; a pressure of 0.01 mm. of mercury suffices.
2. Either the occluded gases should be removed by premelting the iron, preferably *in vacuo*, or it will in general be found necessary to take a series of heating and cooling curves at widely different rates, in order to determine correctly the location of the critical ranges A3 and A2.
3. The iron should be in a single piece entirely surrounding and in contact with the thermocouple junction, otherwise the thermocouple

grate the irregular progress of the heat through the sample curves will lose their sharpness; small samples (1.0 g. or so) give poorer results than large samples.

The interval of recording temperatures should be wide enough so that sufficient sensibility is attained, and narrow enough that the shape of the curves is not distorted; we have found a  $2^\circ$  interval very satisfactory.

The sensibility of the apparatus indicating temperatures and the rate of temperature should be of the order of  $0.01^\circ$  and time of measurement measured to better than 0.2 sec.

From the results of this investigation may be mentioned the fact that the inverse-rate and differential methods, the latter plotted as the derived-differential curve, give identical results and the same sensibility for the critical ranges, and the two sets of curves are strictly similar, save for minor particulars.

The plotted curves give what seems to us conclusive evidence of the definite existence of A3 and A2, all of the 130 curves without exception showing both these critical ranges sharply defined and reasonably distinct. It was found impossible to eliminate or suppress the A2 by thermal treatment. The A2 transformation has not a cusp, nor do there appear to be other transformations above or below A2 between  $300^\circ$  and  $1,050^\circ$ .

For electrolytic iron, unless the sample has been premelted into a single mass, erratic results will be obtained for both A3 and A2, the location of the critical points apparently depending in the main on the rate of heating or cooling. The critical points may even be shifted by over  $50^\circ$ . (See Tables IV and VI.) It is possible, however, to reduce the observations on untreated electrolytic iron to the same temperature basis as the gas-free, compact material by plotting the curves at several rates and reducing to zero rate. This appears to indicate that the gases occluded, mainly hydrogen, play an essential chemical rôle in modifying the iron equilibrium.

With gas-free iron the A3 point is not entirely independent of the rate of heating or cooling, so that it is necessary to reduce the rate to zero rate in order to obtain correct results for A3. The range in the location of A3, for example, with pre-annealed samples was found to be  $876^\circ$  C. at 0.155 deg.-sec. to  $897^\circ$  C. at zero rate. (See Fig. 7.)

Preparations of pure iron, even those containing gases, when reduced to the common basis of zero rate of heating or cooling, have a maximum for the A2 critical range, namely,  $A2 = A_{c2} = 768^\circ \pm 0.5$ . All but one of the 15 samples gave this result within  $2^\circ$ , the other to  $3^\circ$ .

Similarly for zero rate, the values of the maxima of A3 are found to be  $Ac3 = 909^{\circ} + 1$  and  $Ar3 = 898^{\circ} + 2$ .

It was not possible to infer a single equilibrium temperature  $Ac3$  from these experiments, the  $Ac3$  transformation on heating always being at a higher temperature than  $Ar3$ , the transformation on cooling.

It was found, however, that the beginning of  $Ac3$  coincides in temperature with the beginning of  $Ar3$  as closely as could be judged. It is as if the crystallographic change at A3 required, so to speak, a temperature inertia to complete itself both on heating and on cooling, although the effect of rate on the equilibrium (see Fig. 7) appears to be slightly the greater on cooling.

It is possible that the A3 transformation is somewhat more complex than this, as there are indications from some of the heating curves of a doubling of  $Ac3$ , although not of  $Ar3$ . This effect may be fortuitous.

The relative amounts of heat accompanying the two transformations, A3 and A2, are approximately 3 to 1 respectively.

An examination of some of the heating curves will perhaps give the incorrect impression that  $Ac2$  is an evolution rather than an absorption of heat. The swing back at the maximum is very abrupt, following what appears to be a gradual building up of this maximum from an indeterminate low temperature. This behavior would be in accordance with the gradual change in certain physical properties, such as magnetism and electrical resistance, as A2 is approached. On the other hand, the operations carried out on sample F2 (Plate V), failed to diminish sensibly the intensity of  $Ac2$ , which would imply that this thermal transformation is limited to a narrow temperature interval; also some of the curves of  $Ac3$  show that this long back swing appears to be in part at least a property of the heating conditions. The shading off on cooling through  $Ar2$ , if this effect is a real one, might be masked by a similar swing back from this peak, and therefore be indistinguishable.

We hesitate to express an opinion on the nature of the allotropy of iron. These thermal observations appear to show that the transformations A3 and A2 are of the types illustrated in Fig. 8. The fact that A2 appears to be accompanied by no crystallographic change, such as accompanies A3, requiring a violent rearranging of relatively large crystal masses and involving a considerable quantity of heat, may account for the sharpness with which  $Ac2$  equals  $Ar2$ , and the A2 transformation may be merely molecular, not involving the crystallographic structure as such. Whether we have any  $\beta$  iron or not



the region between A2 and A3 will depend on our definition of allotropy, but we hope that we have proved beyond a reasonable doubt that under standard conditions there is a definite transformation at  $768^{\circ}$  and a less well defined although more intense one at  $909^{\circ}$  in terms of their maxima on cooling and heating.

In conclusion, we take great pleasure in acknowledging the samples and analyses from Prof. C. F. Burgess, Prof. H. C. H. Corbridge, Dr. H. Goldschmidt, J. R. Cain, and the American Rolling Steel Company, and the co-operation of the chemical division of this Bureau

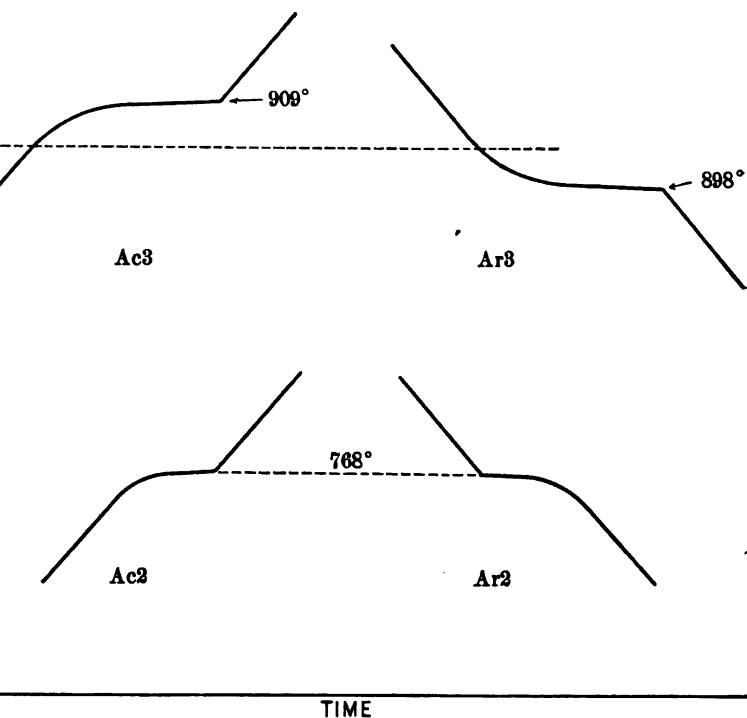


FIG. 8.—TYPES OF TRANSFORMATION IN IRON.

ing check analyses. The care and skill with which H. Scott assisted in taking and reducing the observations has greatly aided the investigation, and we are indebted to H. S. Rawdon for micrographic examinations.

#### BIBLIOGRAPHY.

List of references to the literature of the critical points of pure iron. No pretense of being complete. Many of the papers deal only with the theoretical and controversial aspects of the subject, but it is believed that a sufficient number of titles

concerning the experimental aspects of the subject are included to enable any one readily to get in touch with it. The papers are grouped in terms of the principal phenomenon studied by the authors.

### *General Papers :*

- Arnold, *Jl. Iron and Steel Inst.*, p. 107, No. I ; 1894.  
 Benedicks, *Jl. Iron and Steel Inst.*, 86, p. 242 ; 1912 (contains a bibliography).  
 Charpy, *Bull. Soc. Chim., Paris*. (3) 33, p. 218 ; 1905. (3) 35, p. 188 ; 1906.  
 Howe, *Metallographist*, 2, p. 257 ; 1899.  
     *Metallurgie*, 6, pp. 65, 105 ; 1909 (contains bibliography).  
     *Bull. Am. Inst. Mining Engrs.*, 78, p. 1099 ; 1913.  
 International Society for Testing Materials, Reports, 1910, 1912.  
 Osmond and Werth, *Ann. des Mines*, (8) 8, p. 5 ; 1895.  
 Le Chatelier, *Comptes Rendus*, 129, pp. 279, 331 ; 1899.  
     *Metallographist*, 3, p. 38 ; 1900.  
 Robin, *Carnegie Memoir, Iron and Steel Inst.*, 3, p. 181 ; 1911.  
     *Procs. Int. Assoc. Testing Mats.*, II., No. 8, 1912.  
 Broniewski, *Comptes Rendus*, 156, pp. 699, 1983 ; 1913.  
 Guertler, *Handbuch der Metallographie*.  
 Smits, *Zs. Phys. Chem.*, 76, p. 421 ; 1911.  
 Smits and Leeuw, *ibid.* 77, p. 367 ; 1911.  
 Weiss, *Int. Assoc. Testing Materials*, VII., 2 ; 1910.

### *Expansion :*

- Charpy and Grenet, *Bull. Soc. d'Encouragement*, 102, pp. 464, 882 ; 1892.  
     *Comptes Rendus*, 134, p. 598 ; 1903.  
 Le Chatelier, *Comptes Rendus*, 129, pp. 279, 331 ; 1899.  
 Broniewski, *Comptes Rendus*, 156, p. 1983 ; 1913.  
 Rosenhain and Humfrey, *Procs. Roy. Soc. London*, 83, p. 200 ; 1909.

### *Thermoelectricity :*

- Harrison, *Phil. Mag.* (6) 3, p. 177 ; 1902, 1903.  
 Belloc, *Ann. Chim. et Phys.*, 30, p. 42 ; 1903.  
 Broniewski, *Comptes Rendus*, 156, pp. 699, 1983 ; 1913.

### *Crystallographic :*

- Osmond, *Ann. des Mines*, (9) 17, p. 110 ; Jan., Aug., 1900.  
     *Metallographist*, 3, pp. 181, 275 ; 1900.  
 Osmond and Cartaud, *Ann. des Mines*, (9), 18, p. 113 ; Aug., 1900.  
     *Metallographist*, 4, pp. 119, 236 ; 1901.  
 Rosenhain and Humfrey, *Procs. Roy. Soc. London*, 83, p. 200 ; 1909.  
 Stead and Carpenter, *Jl. Iron and Steel Inst.*, Sept., 1913.

### *Mechanical Properties :*

- Rosenhain and Humfrey, *Procs. Roy. Soc.*, 83, p. 200 ; 1909.  
     *Jl. Iron and Steel Inst.*, 87, p. 219 ; 1913 (contains a bibliography).

### *Electrical Resistance :*

- Benoit, *Comptes Rendus* 76, p. 342 ; 1873.  
 Auerbach, *Wied. Ann.* 5, p. 289 ; 1878.  
 Boudouard, *Bull. Soc. d'Encouragement* 102, p. 449 ; 1903.  
 Callendar, *Phil. Trans.* 178, p. 161 ; 1887.

- Trausch, Wied. Ann. 33, p. 42; 1888.  
 Chatelier, Comptes Rendus 110, p. 283; 1890.  
 Kinson, Phil. Trans. A. 180, p. 443; 1889.  
 and Fleming, Phil. Mag. (5) 36, p. 271; 1893.  
 is, Phil. Mag. (5) 44, p. 213; 1897.  
 and Diesselhorst, Wiss. Abh. P. T. R. 3, p. 269; 1900.  
 ison, Phil. Mag. (6) 3, p. 177, 1902.  
 olai, Phys. Zts. 9, p. 367; 1908.  
 usler, Verh. Phys. Ges. 10, p. 344; 1903.  
 Meyer, Verh. Phys. Ges. 13, p. 680; 1911.  
 iewski, Comptes Rendus 156, p. 699; 1913.  
 rville, Phys. Rev. 31, p. 261; 1910.

### *Electric Measurements :*

- Kinson, Phil. Trans. 180, p. 443; 1889.  
 is, Phil. Mag. (5) 44, p. 213; 1897.  
 urie, Ann. Chim. et Phys. (7) 5, p. 289; 1895.  
 s and Beck, Jl. de Phys. (4) 7, p. 249; 1908.  
 s and Foëx, Jl. de Phys. (5) 1, p. 274, 744, 805; 1911.  
 Terry, Phys. Rev. 30, p. 133; 1910.  
 la and Takagi, Tokyo Imp. Univ. Sci. Reports 1, p. 207; 1912.  
 Rev. de Métallurgie 10, p. 146; 1913.

### *Metallurgy of Iron :*

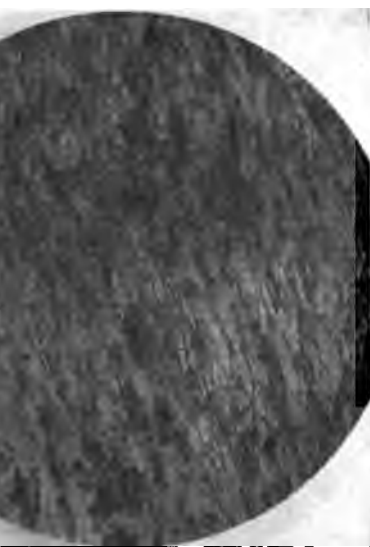
- chon, Ann. de Chim. et de Phys. (6) 11, p. 33; 1887.  
 er, Phil. Mag. (6) 10, p. 430; 1905.  
 hoffer, Metallurgie, 4, p. 427; 1907.  
 s and Beck, Jl. de Phys. 7, p. 249; 1908.  
 echer, Verh. D. Phys. Ges. 9, p. 647; 1907.  
 chen, Ferrum, 1, p. 1; 1912.

### *Chemical Analysis :*

- enter and Keeling, Jl. Iron and Steel Inst. I, p. 224; 1904.  
 Collected Researches Nat'l Phys. Lab. I, p. 227.  
 hort, Metallurgie, 4, p. 617; 1907.  
 ond, Mem. de l' Art. de la Marine, 15, p. 573; 1887.  
 Ann. des Mines, (8) 14, p. 5; 1888.  
 Jl. Iron and Steel Inst., p. 38, No. 1; 1890.  
 Metallographist, 2, p. 169; 1899.  
 Rev. de Métallurgie, 3, p. 551; 1906.  
 rts-Austen, Procs. Inst. Mech. Engrs. p. 543; 1891; p. 35; 1899.  
 py and Grenet, Bull. Soc. d'Encouragement, 102, p. 464; 1903.  
 er, Metallurgie, 6, p. 145; 1909 (contains bibliography).  
 ld, Jl. Iron and Steel Inst., p. 107, No. 1; 1894.  
 Int. Zs. Metallographie, 1, p. 192; 1911.  
 British Assoc. Reports (Sheffield), 1910.  
 Williams and Barnes, Jl. Iron and Steel Inst. p. 246, No. 1; 1910.  
 Moore, Jl. Iron and Steel Inst. p. 268, No. 1; 1910.  
 ens and Meyer, Metallurgie, 7, p. 307; 1910.  
 let et Portevin, Comptes Rendus 156, p. 702; 1913.  
 enter, Jl. Iron and Steel Inst. 87, p. 315; 1913. (Followed by very full discussion.)  
 iewski, Comptes Rendus, 156, pp. 699, 1983; 1913.



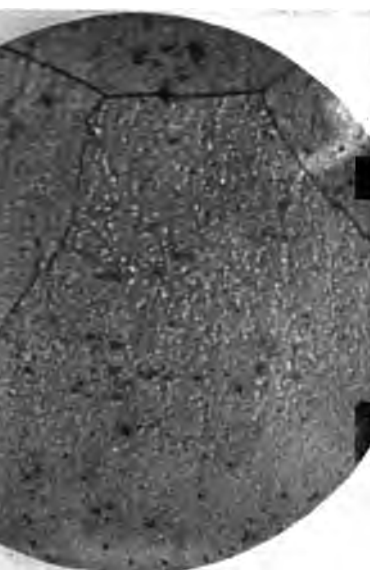
PLATE I.—PHOTOGRAPH OF APPARATUS.



Cain's Electrolytic Iron as Deposited.  
is perpendicular to the electrode.



Fig. 2.—C. F. Burgess's Electrolyte Iron heated  
to 1,050° several times but not remelted.



The same at 500 X. Small bubbles are  
seen at this magnification.

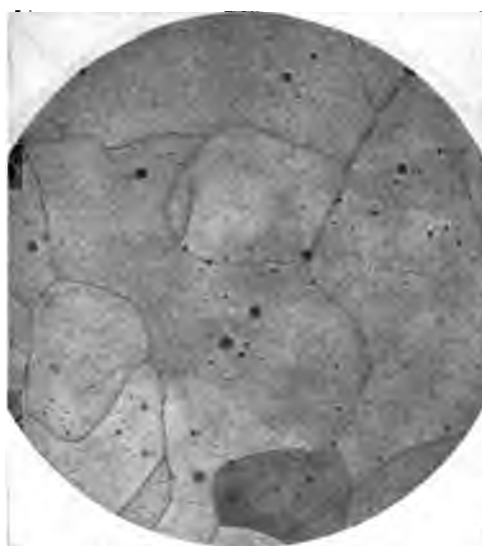


Fig. 4.—Cylinder A. Remelted from American  
ingot iron in the gas furnace.

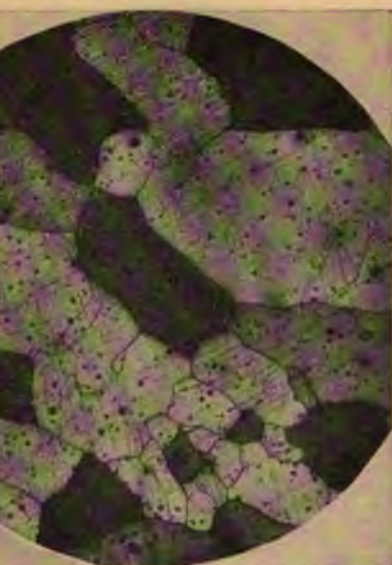


Fig. 5.—Cylinder Ag. Cylinder from Cain's electrolytic iron, remelted in gas furnace.

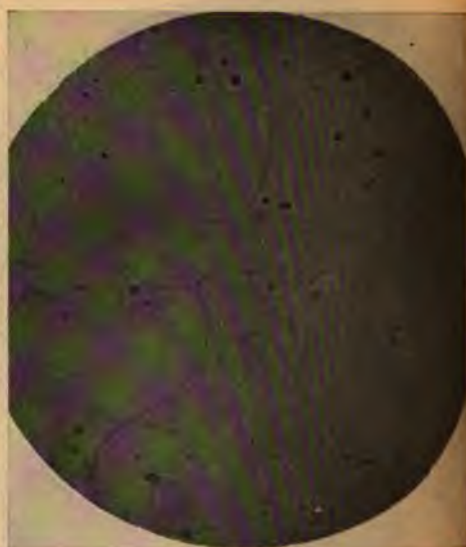


Fig. 6.—(Langheim-Pfanhauser) Cylinder No. 23, remelted in Arsem furnace *in vacuo*.



Fig. 7.—Cylinder Ag, Langheim-Pfanhauser, remelted in gas furnace.

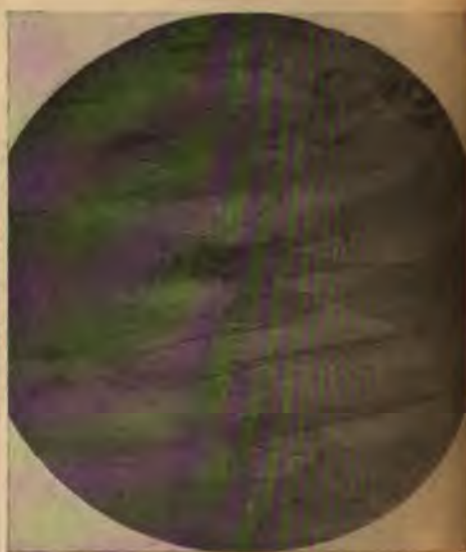


Fig. 8.—Same as Fig. 1, but 250 diameters.

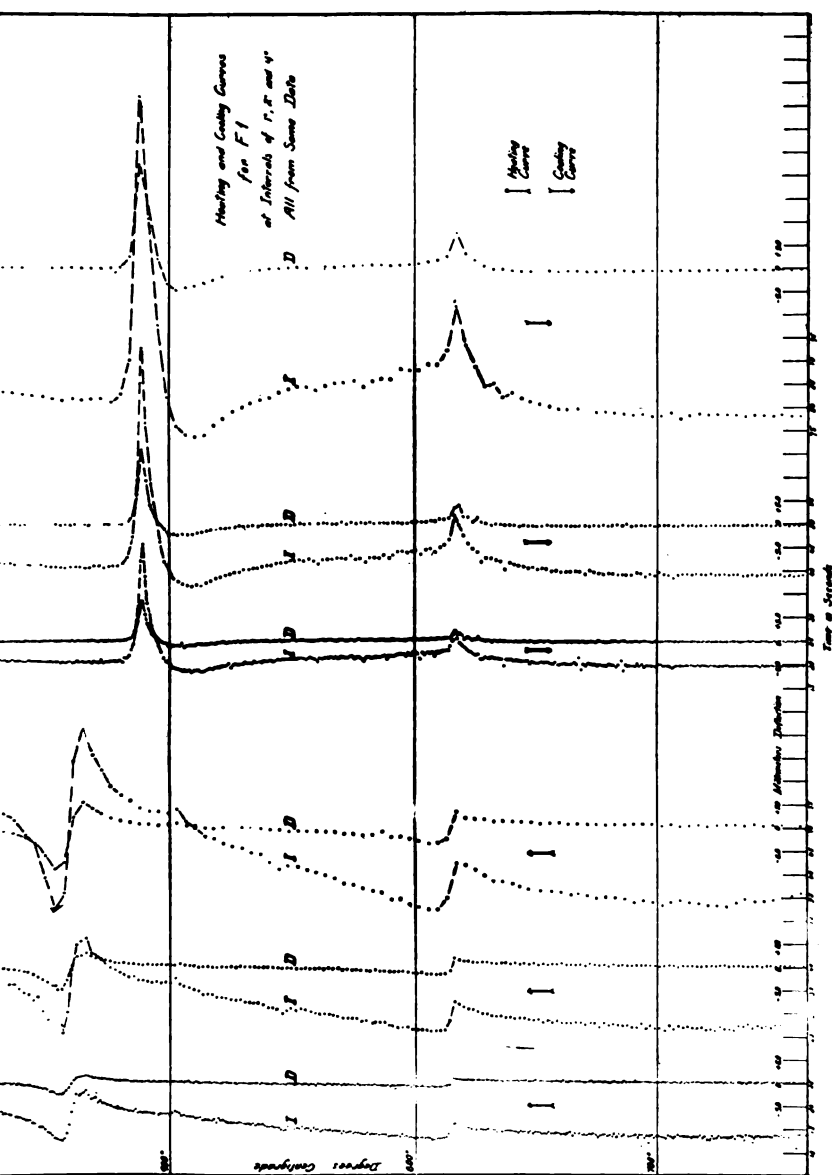
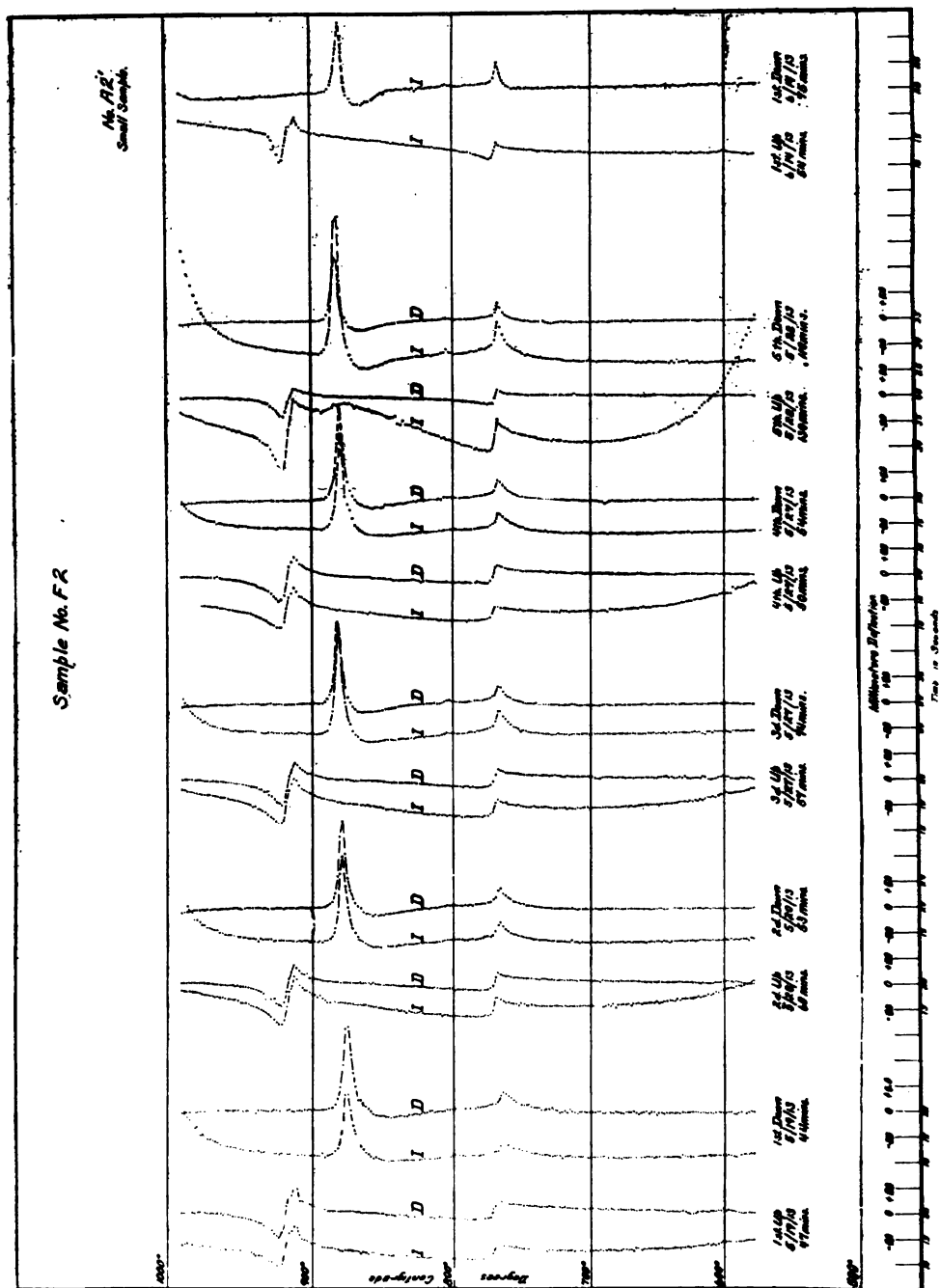
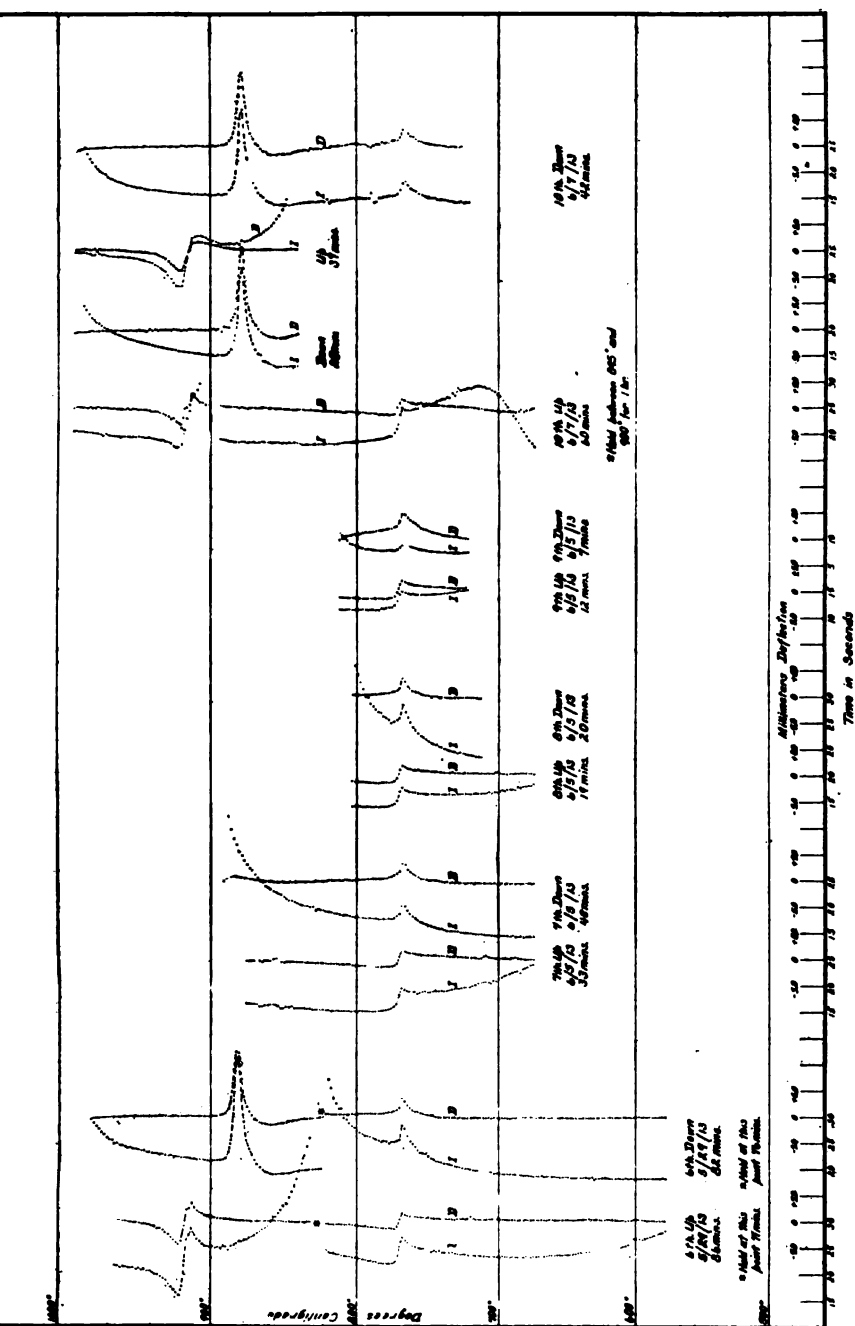
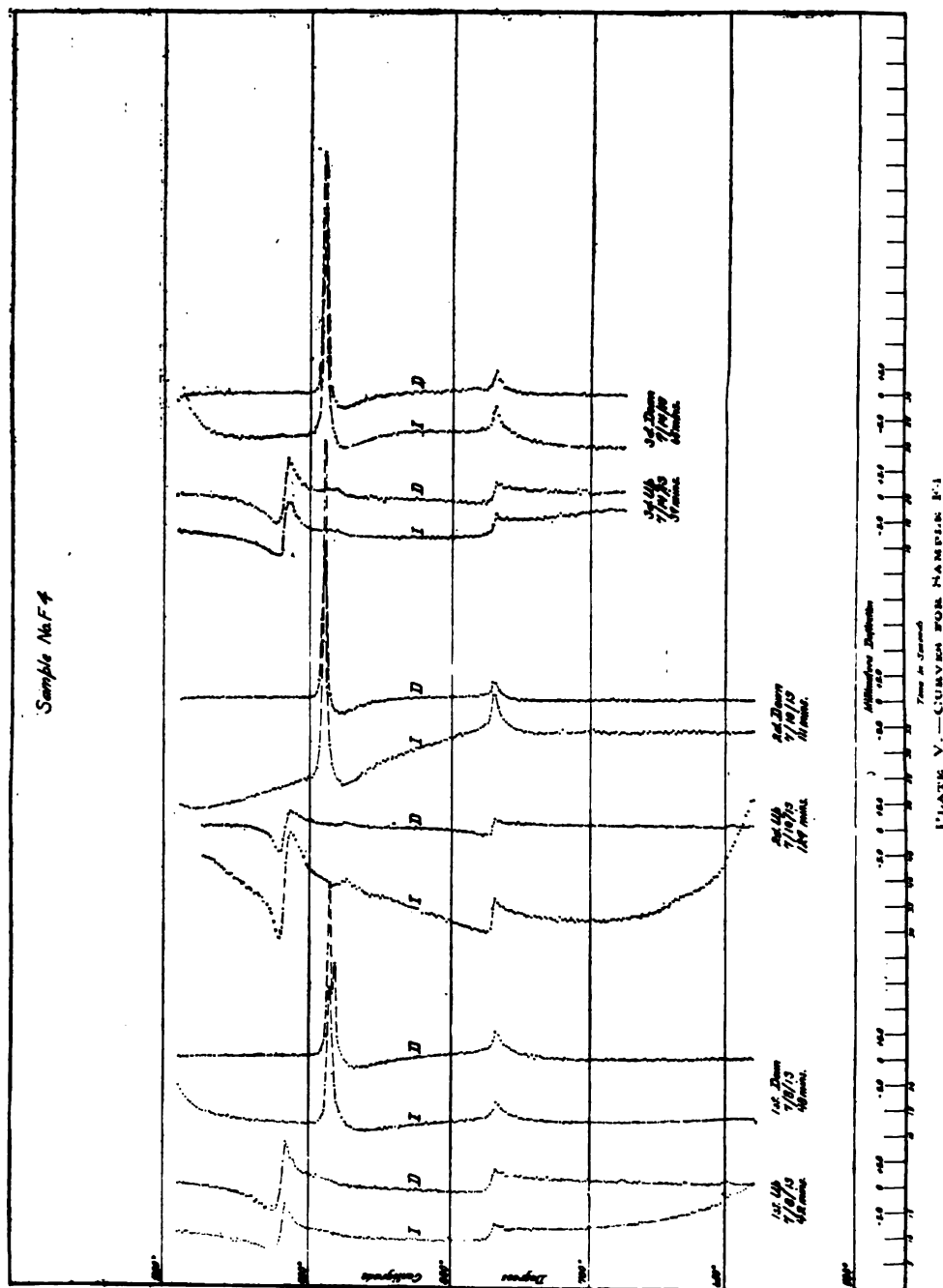


PLATE III.—EFFECT OF DIFFERENT INTERVALS, SAMPLE FI.









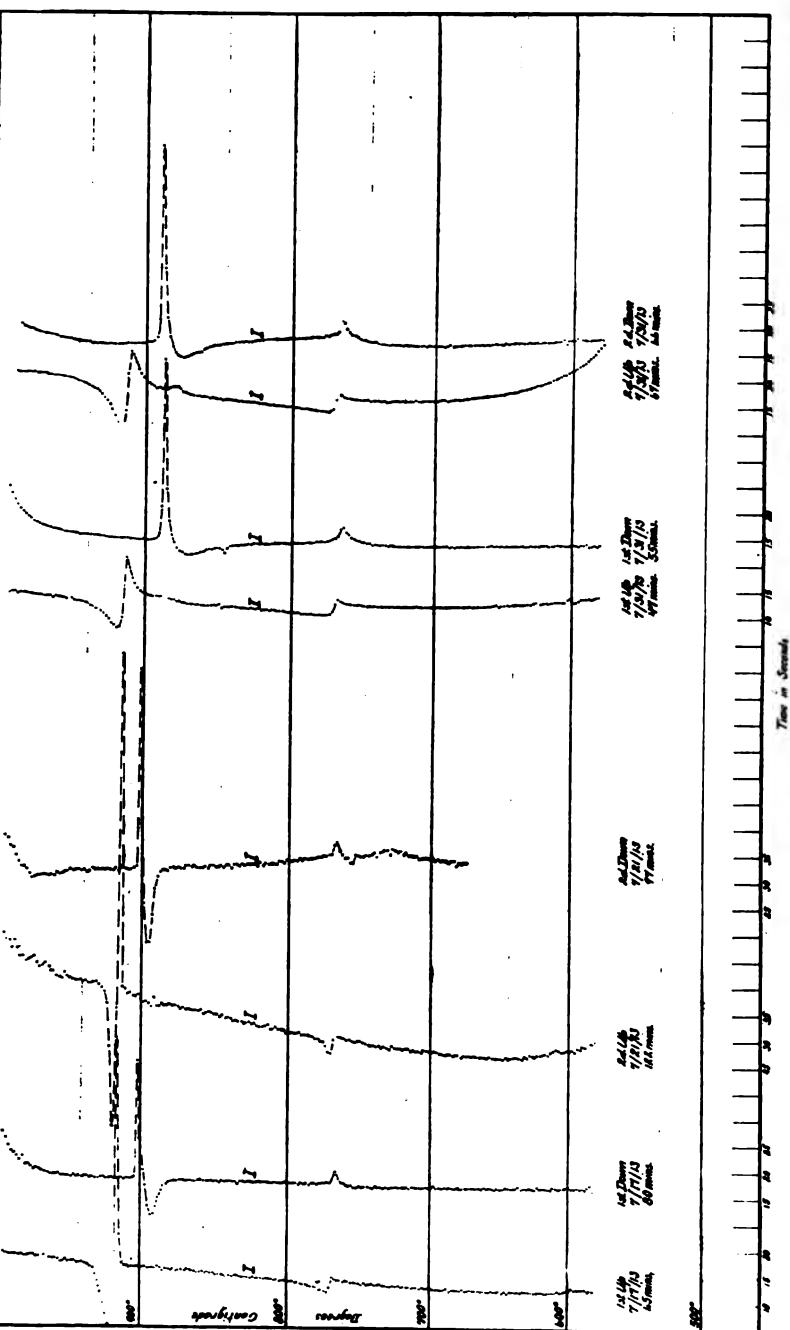
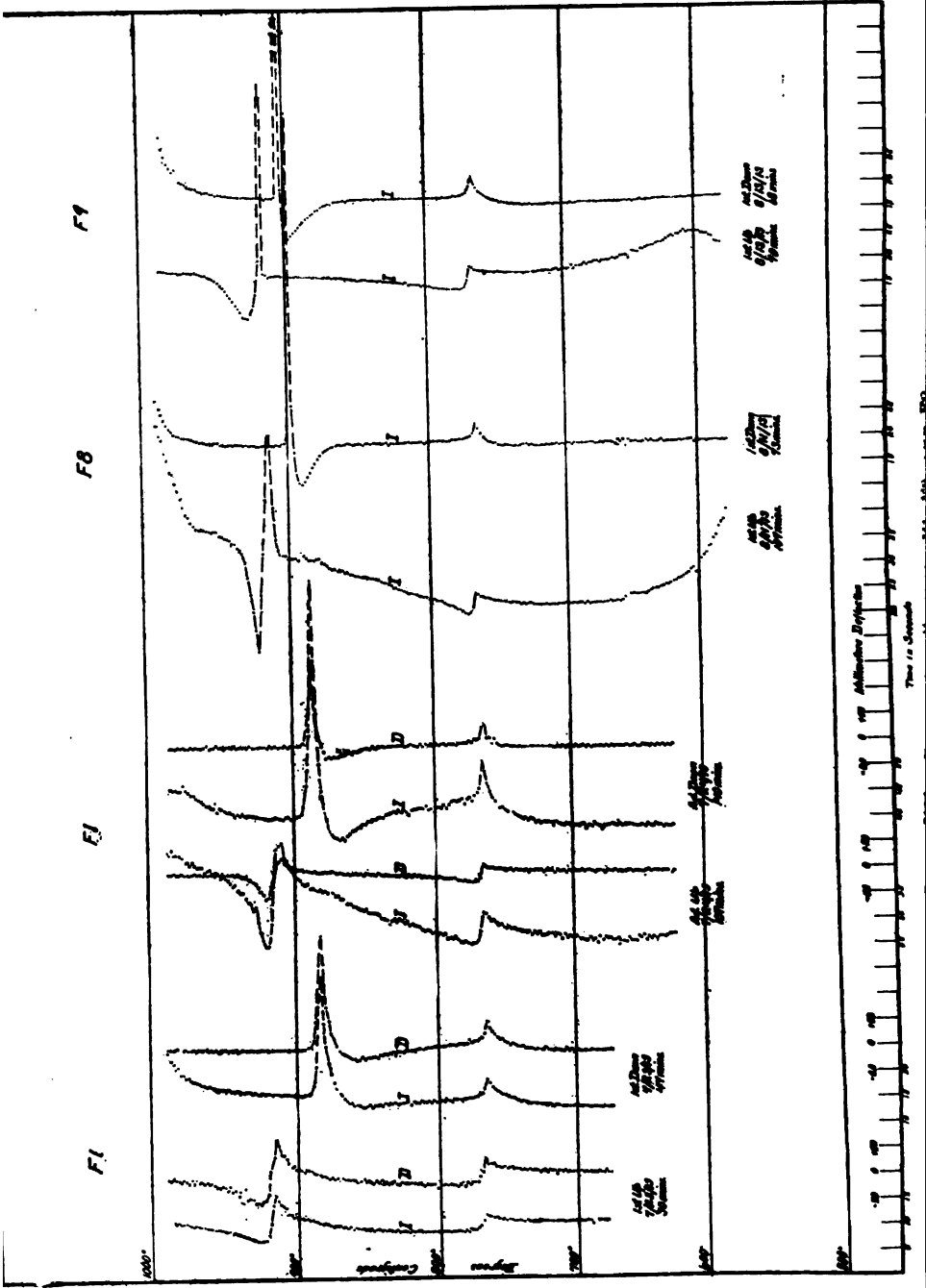


PLATE VI.—CURVES FOR SAMPLES F5 AND F7.



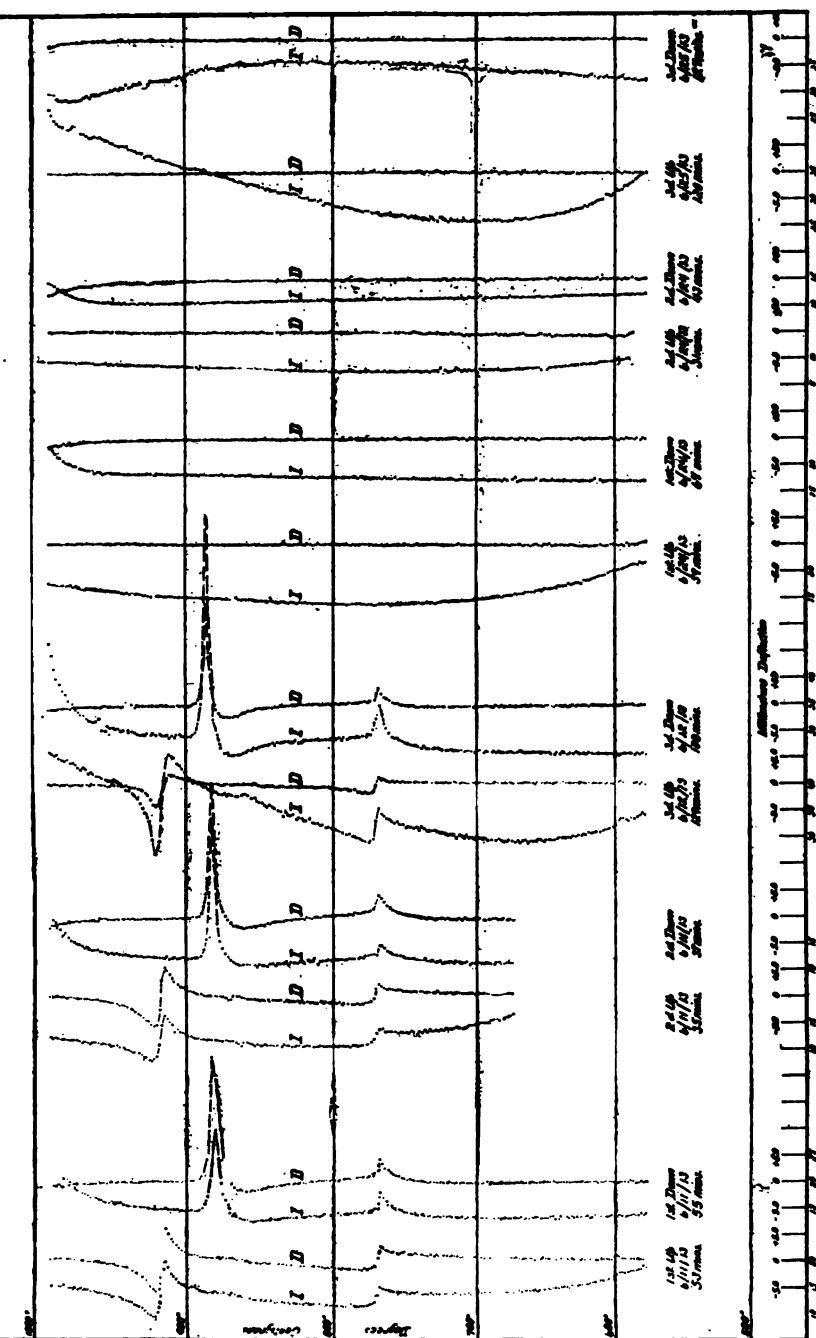
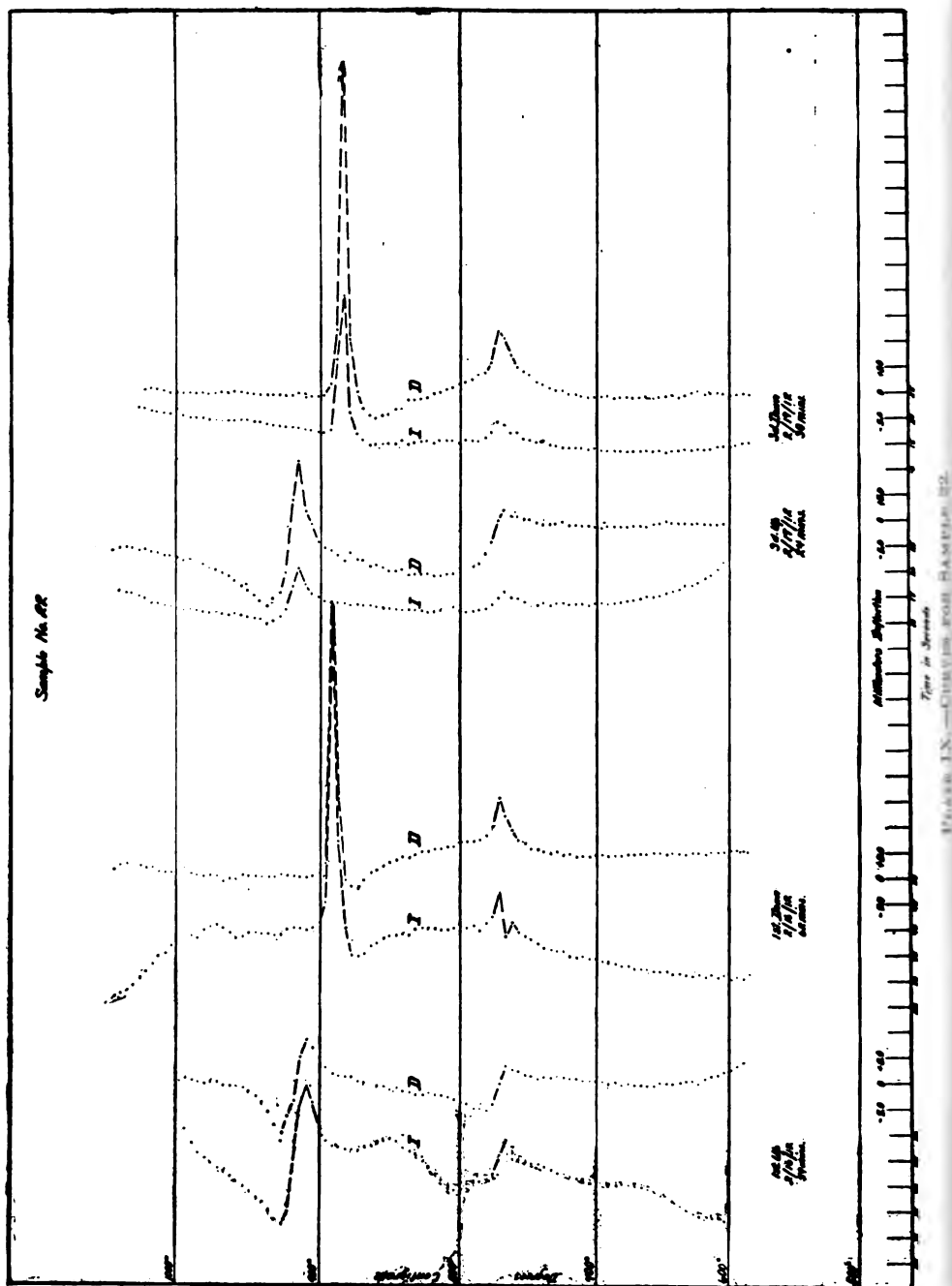


PLATE VIII.—CURVES FOR SAMPLE F3 AND Pt-Pd BLANK.



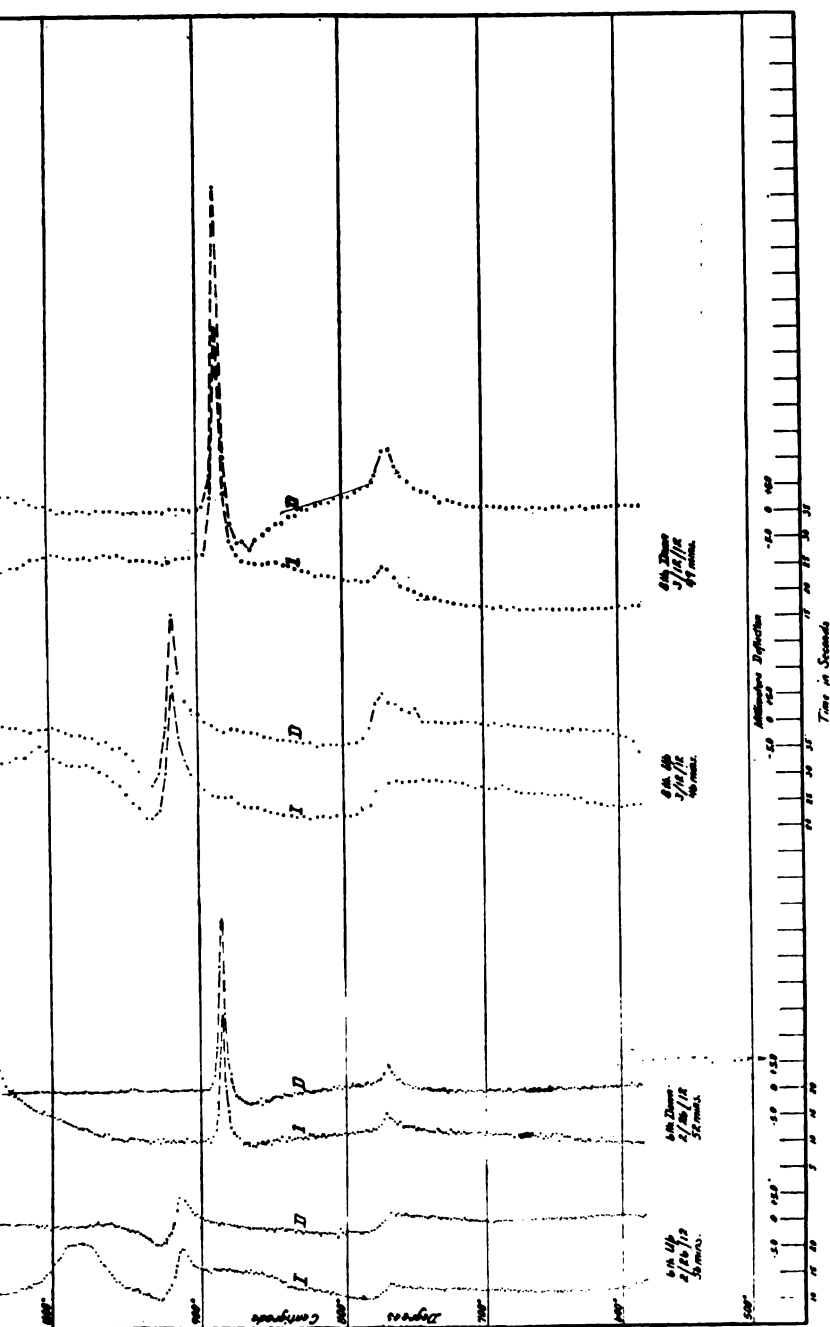


PLATE IXA.—CURVES FOR SAMPLE 22.

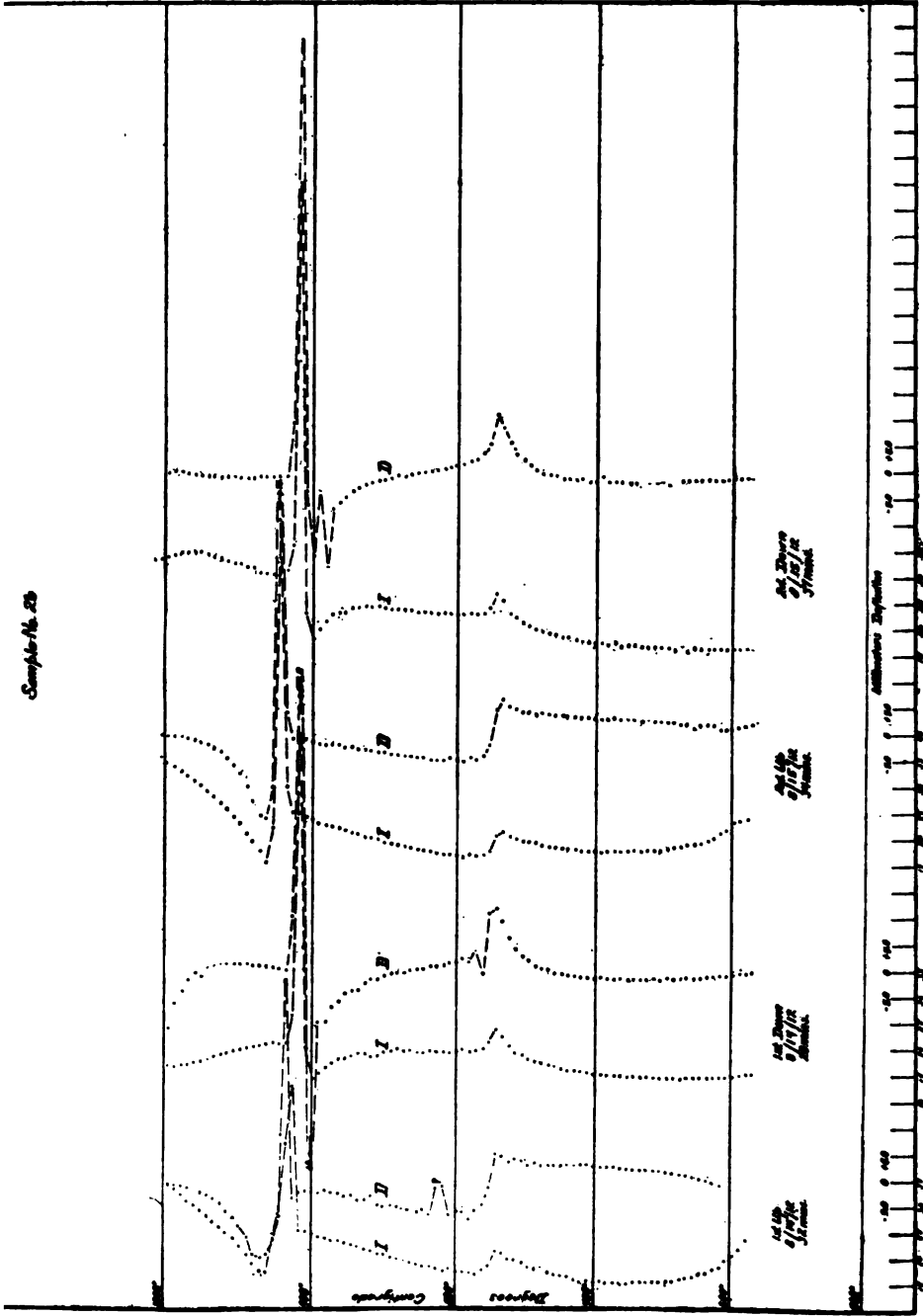


PLATE X. CURVES FOR SAMPLE 25.



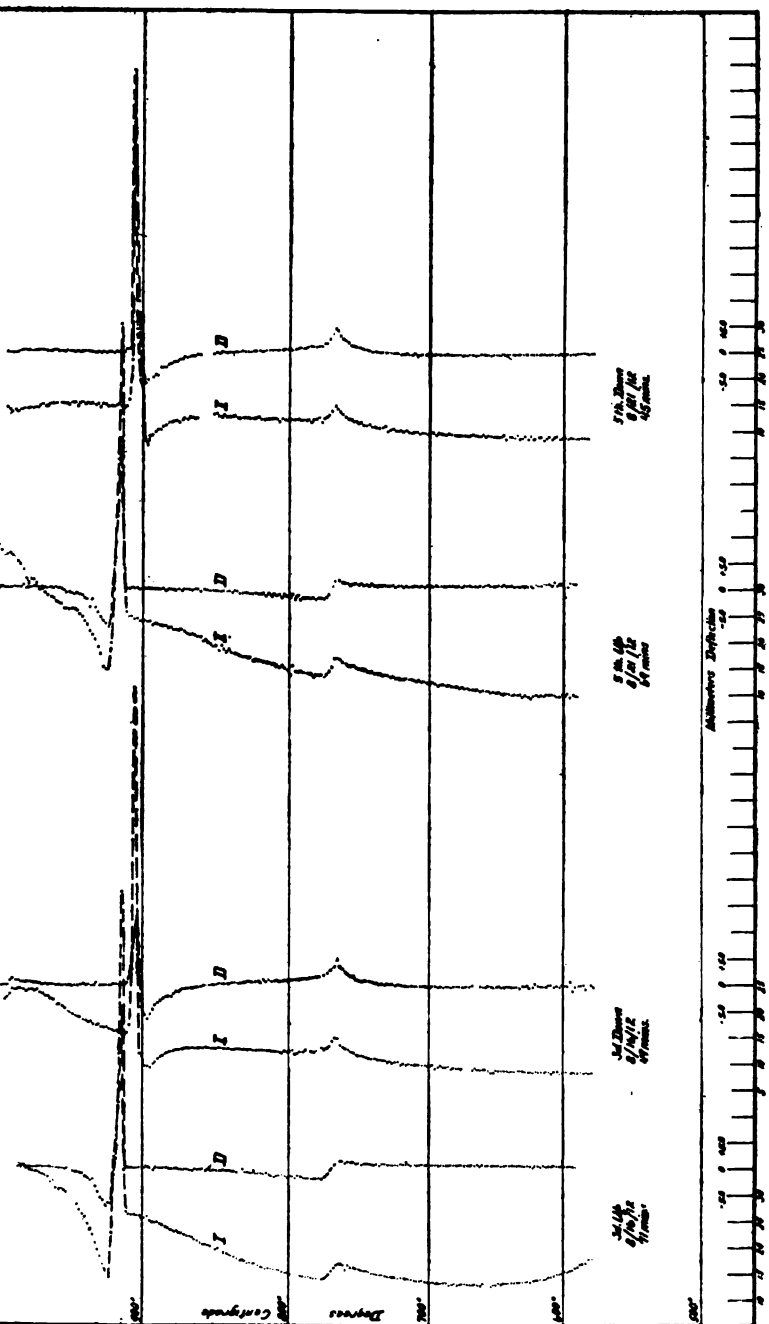
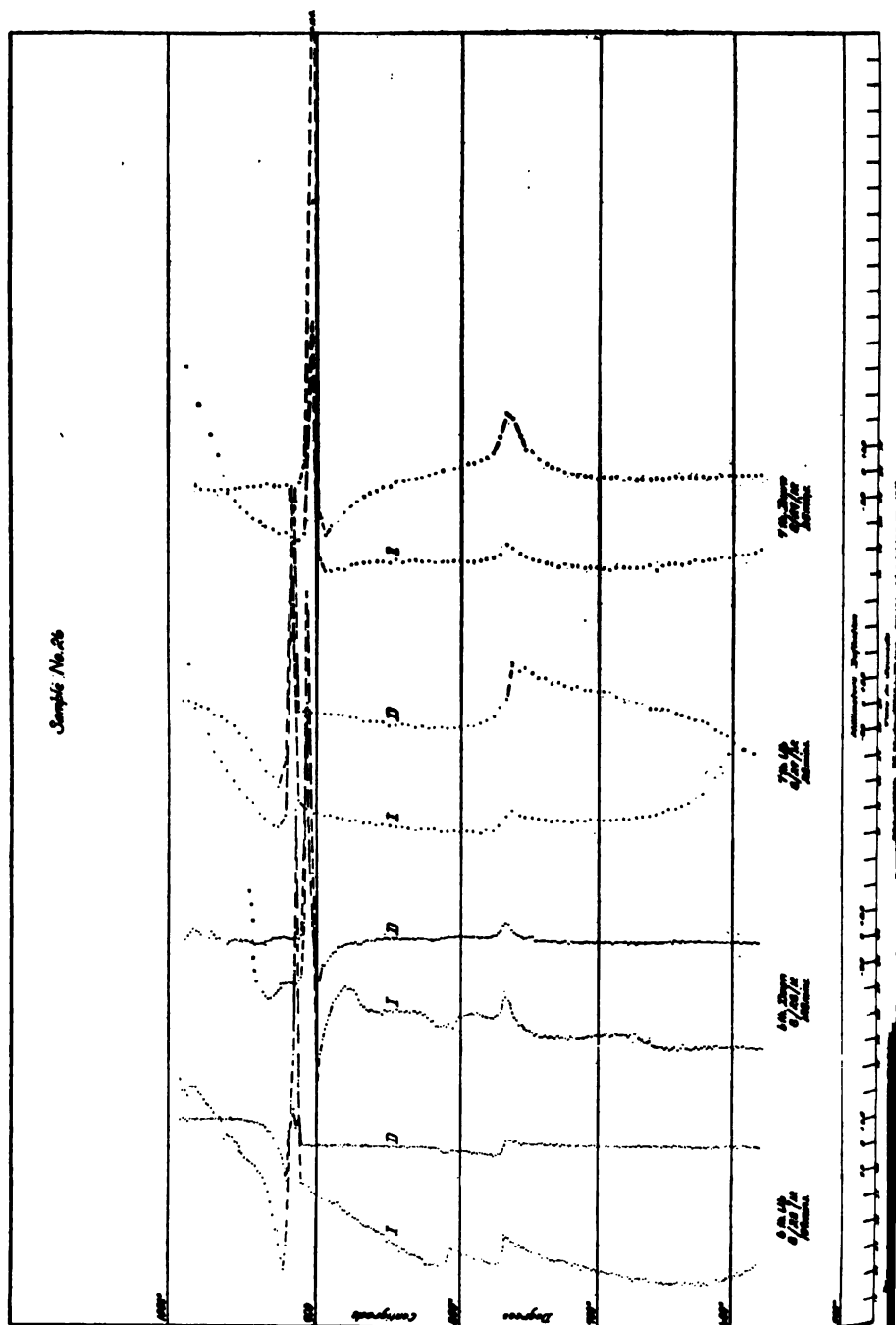


PLATE XA.—CURVES FOR SAMPLE 26.



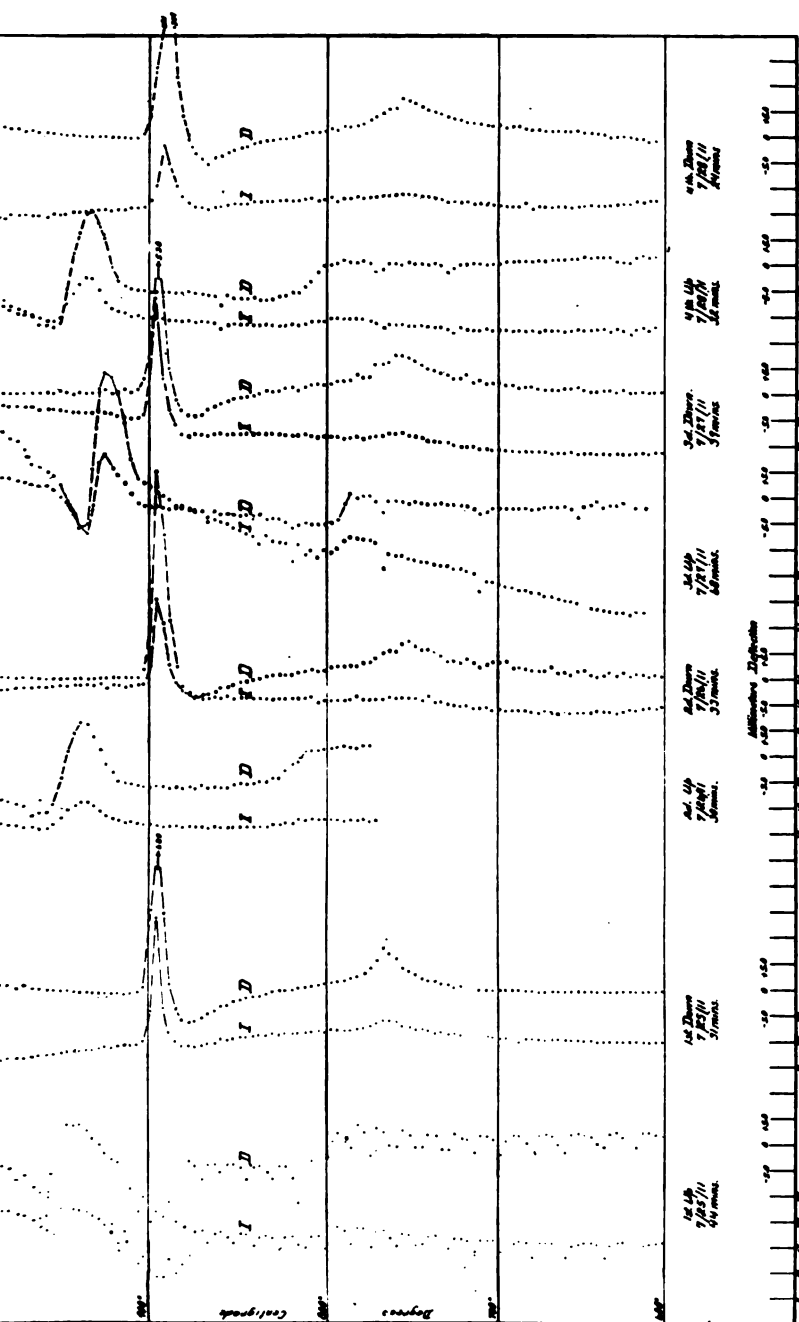


PLATE XI.—CURVES FOR SAMPLE NO. 1.



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, October, 1913, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Dec. 1, 1913. Any discussion offered thereafter should preferably be in the form of a new paper for publication in Vol. XLVII. (with suitable cross-references in both volumes).

## The Future of the Chilled Car Wheel.

BY P. H. GRIFFIN, NEW YORK, N. Y.

(New York Meeting, October, 1913.)

WHEN a subject, such as the manufacture and service of chilled car wheels, as has been fruitlessly discussed for ten or fifteen years, it is difficult to revive interest and action by the mere repetition of statements and arguments that have been made before.

And when a situation involves serious responsibilities for conditions that have grown up under circumstances beyond the control of any particular individuals or authority, it is even more difficult to deal with. But there is one phase of every subject that need not involve these particular points if presented in a proper manner; and that is, "the future state."

I will try to present the subject of this communication from the latter standpoint and with the hope that all of those interested will feel disposed to give the matter attention from the basis that it is a vitally important one to all that travel on railroads, whether as employees or officials, or as dependent on those in charge of the operation, or in the matter of materials and equipment used.

The conditions of chilled wheel service have been changed so radically in the past ten or fifteen years by the use of freight cars of 40 and 50 tons capacity, that it is fair to say in the interest of all concerned in the use and in the manufacture of such wheels, that the increased strains and loads have been quite sufficient to account for much of the service results that have transpired.

That proper provision was not made for increased possibilities of strength and wear, in fact that previous factors of the kind were allowed to deteriorate, is no proof that such wheels cannot be made equal to heavy service conditions as shown in the data given herein.

It was somewhat remarkable that a radical change occurred in the important factor of price paid for chilled wheels about two or three years before the possible use of the 50-ton car was seriously entertained. In 1893 the price for chilled wheels used for renewals and

repairs, which is determined and fixed by the Rules of the Master Car Builders' Association, was reduced about 25 per cent. from the basis at which it had stood for the preceding 10 or 15 years; and in 1895, a further reduction of about as much more was made.

This brought the net price that any railroad could charge for wheels used for renewals and repairs, made on cars belonging to any other railroad or owner, down to about 60 cents per 100 lb. plus the delivery of an equal weight of worn-out or failed wheels. General business conditions about that time were such that very severe competition existed in the purchase and sale of all material having to do with railroad equipment.

Between 1895 and 1900, the price of chilled car wheels used under new cars did not exceed an average of one cent per pound. This price covered the entire payment made for the wheel. It is manifest that such a change in price conditions was bound to affect in a very serious manner the quality of material used and the kind of workmanship that could be devoted to the manufacture.

By 1900 the use of freight cars of 50 tons capacity had passed the point of experiment so far as successful construction was concerned, and during the next five years the number of such cars built increased from year to year.

Between 1905 and the present time this increase has been more rapid from year to year, until the number of such cars amounted, as it now does, to nearly one-third of the entire total of freight cars in use. This figure is approximate and may be a little in excess of the present proportion, but the total number of cars of 40 tons capacity in use, taken together with the 50-ton cars, will undoubtedly bring the total of both classes somewhat over the half of all freight cars in service. This radical change has taken place principally since 1895, the date at which the reduction in M. C. B. price of chilled wheels was made.

It will be seen, therefore, that during a period of about 15 years the price of the chilled wheel had been at a point nearly 50 per cent. below the price per pound that previously prevailed, while the load carried per wheel and the general severity of service conditions increased in about the same proportion.

Whatever the shortcomings of the chilled wheel may have been under such conditions, it is necessary to make due allowance for this fact, and whatever the possibilities of its future service may be, it is equally necessary to make provision for such change in the M.C.B. price as will admit of the use of the quality of material and manufacturing practice that will be at least equal to the quality used before the reduction in price was made.

the discussions that have taken place, it is probable that no impression has ever been made upon the mind of the average railroad official as to what this necessary difference should be. From a fairly intimate knowledge of the cost of manufacture and material used during some 15 or 20 years prior to the standard of the same during the interval since 1895, I may say that an advance of \$2 per wheel in the M.C.B. price for 33-in., 725-lb. wheels, the standard for 50-ton car service, will be sufficient to provide for the use of materials and manufacturing process, equal to any used in the first period referred to. And that the scrap value of such wheels, because of the better quality of material in them, will be 75 cents more than the present M.C.B. price for worn wheels. The present M.C.B. price for wheels of diameter and weight named is \$9, and the present M.C.B. scrap allowance for the worn or failed wheel is \$4.75, making the net price per new wheel \$4.25, the latter being all that can be charged by any railroad, per wheel for wheels used for renewals and repairs, and the change suggested would make the price of the new wheel \$11; the price of the worn or failed wheel \$5.50, and the net charge that could be made for the new wheel.

It is not probable that any exception would be taken to the payment of this advance in price by any owner of 50-ton cars, provided there is a reasonable certainty of getting proportionately better service upon the payment of the difference.

The Wheel Committee of the Master Car Builders' Association discussed the subject of the quality and section of chilled wheels at its formal and informal committees representing the chilled car wheel makers, and in 1908 standard sections were adopted as the result of the conferences held during the preceding three or four years. An informal committee, representing the wheel makers, and the Wheel Committee of the M.C.B. Association.

When this action was taken, the latter committee desired to take as the subject of standard specifications covering the quality of material and the details of manufacturing practice to be used. Nearly all chilled wheel makers in the country joined in the formation of an incorporated association known as the Association of Chilled Wheel Makers, and this association has discussed the subject with the Wheel Committee of the M.C.B. Association from year to year without arriving at any agreement upon the matter.

The manufacture and use of the rolled steel wheel began experimentally about the time that the construction of the 50-ton capacity car was commenced, and after passing through the usual experimental

stages of manufacturing, plant, equipment, etc., the making of such wheels has become quite well established in one or two of the Eastern States.

When such wheels were first made and used it was claimed that the life of the same would be about equal to that of the steel-tired wheel, but that claim was based on the idea of turning down the tread of the rolled steel wheel, when worn, and to secure in this manner three or four periods of life instead of the single period embraced in the use of the chilled wheel. This practice was never carried out to any extent, and whether it is now or may be, in the future, will depend on whether railroads are prepared to install the necessary plant for doing such work and make it a part of their regular shop practice. Such a change, if made, will be quite a radical one compared with the more simple practice associated with putting in service and replacing chilled wheels. That such practice has not been carried out to any considerable extent by the railroads that have made the most extensive use of the rolled steel wheel is clearly indicated by the number of such wheels sold as scrap after the first removal from service.

It is quite possible that with the improvement in the quality of the rolled steel wheel which is certain to be made from year to year, the practice of turning down the treads and flanges will be extended, and as such practice is and has always been general, in the case of wheels used under passenger cars and locomotives, it will not involve anything new except the additional and quite heavy investment necessary to provide for the work and the cost of carrying it on.

The rapid increase in wear at the junction of flange and tread, known as the "throat," introduces quite a different condition with respect to the turning down of treads and flanges of wheels used in heavy freight car service, because, regardless of the wear on tread, sufficient metal must be taken from both tread and flange to form a new and proper contour of both. A wheel that is worn to the M. C. B. limit of flange wear, will require the removal of at least  $\frac{3}{8}$  in. of metal from the tread section or  $\frac{1}{4}$  in. from the total diameter to restore the proper flange section. Considering the fact that the best wear is obtained from the outer section of the metal, it may be seen that there are some vital questions involved in the practice described.

One thing, however, is quite clear. The wheel used under cars of 50 tons capacity must be equal to the service demands upon it to the best of the ability of those responsible for the conditions of such service to obtain such wheels, and the question of cost or type of wheel must be secondary, in the long run, in this respect.

It is important, therefore, in considering the possibilities of the



wheel in 50 ton car service, to obtain all possible data as to performance of such wheels under service conditions of like or that have approached the same.

Up to 1895, the use of charcoal pig iron in the manufacture of chilled wheels was quite general, and up to about 1890 about 50 per cent of such metal was generally used by chilled wheel makers.

The mixture used between 1880 and 1890 by one of the large manufacturers of chilled wheels, consisted of a total of 1,800 lb. of charcoal pig iron out of a total charge of 3,400 lb. put into the furnace. This 1,800 lb. of charcoal pig iron consisted of 1,600 lb. of Superior charcoal iron and 200 lb. of Southern charcoal iron. This mixture was considered, at that time, as of an ordinary character for chilled wheels used under locomotives and passenger cars. The mixture would have consisted of a larger proportion of the expensive charcoal irons made in small furnaces in the Eastern and Southern States. But it is interesting to note that even for very rich mixtures, at that time, 50 per cent. of the total quantity consisted of charcoal pig iron.

The use of the lower cost mixtures containing coke pig iron and hardened with steel scrap, and given a certain chilling quality by the addition of ferro-manganese, began about 1888; and as it was found to produce chilled wheels that would give the same results in test as those made from charcoal iron mixtures, it is easy to see how and why the business fell more and more, from year to year, into the hands of wheel makers developing and carrying on such a business. There is no doubt that the reductions in price made in competition with competition to secure orders brought the price of chilled wheels down to a basis that largely accounted for the reduction made in the M.C.B. price in 1893 and 1895.

About the same time the use of the "drop" and "thermal" tests became more universal, and the application of such tests to wheels for monthly renewal and repair orders issued by the railroads, became more general. There is no doubt that these tests were relied upon very largely by railroad officials to determine the quality of cars purchased, and that they were valuable to that end. Such tests, however, were increased in severity from year to year, and it is evident that about 1900 the quality of wheels made under such conditions was governed more by the necessity of getting the wheels to pass the tests, than by the fitness of the wheels to resist the service conditions that caused more rapid wear and failure.

Up to 1900 the recasting of wheels removed from service, which had been made out of the charcoal iron mixtures, retarded the

effect of the new practice so far as service results were concerned. Between the year 1900 and the present date, and as wheels have been recast into new ones, this condition has been less and less effective from year to year.

The report of the Interstate Commerce Commission for the year terminating June 30, 1912, gives the statistics of derailments caused by broken and failed wheels. These statistics show that 2,520 derailments were due to broken and burst wheels, 6,020 were due to broken flanges, and 999 were due to miscellaneous wheel failures, making a total of nearly 10,000 derailments due to wheel failures out of a total number of derailments due to defective equipment, of 28,904. These statistics cover the period 1902 to 1912 inclusive, or eleven years, and show a much heavier increase in the number of derailments due to wheel failures than can be accounted for by the number of freight car wheels in use, as the same increased from year to year.

The total number of such wheels in use is about 20,000,000, and the annual capacity of the chilled car wheel makers, included in the membership of the wheel makers' association, is given in the *Proceedings* of the M. C. B. Association for 1909 as about 6,000,000 wheels, based on the output per day for the different makers of about 20,000 wheels, as stated in the report of the M. C. B. Wheel Committee in the *Proceedings* for that year.

If the annual output was fully maintained, it would mean the making of a sufficient number of wheels to renew the entire total in use in periods of less than four years each, but it is probable that the output is not always so maintained, although it must be nearly so.

The statistics referred to do not distinguish as to the type or kind of wheel that caused each derailment, and it must not be supposed that the failure could be attributed to chilled wheels in any particular proportion as compared with the steel wheels, either of the rolled or steel-tired type. Although no such complete statistics have been heretofore published, the figures that have been published, from time to time, with respect to the breakage of steel or chilled wheels, have not indicated that the latter differ particularly from the former.

A peculiar feature of a number of very serious derailments in recent years is the breakage of wheels under heavy capacity freight cars at the particular time when passenger trains were passing, and the derailment of the passenger train, due to striking the débris of the freight cars thrown on the passenger tracks so suddenly that there was no time to do anything to prevent a wreck.

About three years ago, on a leading Eastern railroad, a wheel

der a heavy capacity freight car when the latter reached the severe grade, and at the very moment when an express train, down a severe grade in the opposite direction, reached the ce. The point in question was a valley at the foot of the two ades. The locomotive of the express train struck the wreck- e freight train with such an impetus that the second express brown bodily up in the air, over the first express car and the ye, and on the track ahead. This description of the wreck n at the time in the daily papers and was referred to as being markable in its conditions. The construction of the express have been of the steel-frame type, and this undoubtedly d for the peculiar result that took place. The present ten- go to the use of steel car construction evidently has possibil- kind that has not been hitherto experienced, and that make ecessary to leave nothing undone to secure every condition uction and operation that will increase the factor of safety. . en 1890 and 1895, locomotives of 100 tons total weight were the Michigan Central Railroad, Canada Southern Division. . of the weight was on the driving wheel, 21,840 lb. was on e forward truck. The weight of tank, empty, was 43,000 weight of the water carried, when tank was full, was 31,160 weight of coal carried, when engine tender was loaded, was . The total weight of engine and tank, the latter loaded, 206,000 lb.

mileage record of 308 wheels, out of 384 used under these ves, showed as follows:

|                      |                           |
|----------------------|---------------------------|
| 122 wheels made..... | 60,000 to 75,000 miles.   |
| 97 wheels made.....  | 75,000 to 100,000 miles.  |
| 39 wheels made.....  | 100,000 to 154,437 miles. |
| 1 wheel made.....    | 181,446 miles.            |
| 37 wheels made.....  | 40,000 to 60,000 miles.   |
| 9 wheels made.....   | 30,000 to 40,000 miles.   |
| 2 wheels made.....   | 25,000 to 30,000 miles.   |
| 1 wheel made.....    | 20,755 miles.             |

ty-six wheels were "good" when removed, though taken out nt of wear on opposite wheel, and were put back in other Not one of the wheels failed on account of breakage of any

locomotives were used in fast passenger service, frequently at over 60 miles per hour, and were first equipped with steel- eels. As the latter were replaced, 33-in. chilled wheels, g 650 lb. each, made from mixtures of selected charcoal iron, d with the above results.

This special instance is given in some detail to show the possibilities of chilled wheels made out of good charcoal iron and of the weight and section indicated, which is nearly 100 lb. below the weight and section of wheel now used under freight cars of 50 tons capacity.

In this particular case the chilled wheels were used under both the locomotive tenders and the locomotive trucks, and thus the load per wheel was carried to the amount of 94,000 lb. on the driving wheels, and the remaining load of 112,000 lb. was carried on the eight wheels under each tender and the four wheels under each forward truck, thus bringing the average load per carrying wheel down to about 9,500 lb.; the fact that the eight tender wheels were all equipped with brakes and had to resist the excessive heating involved in the control of such high speed service, and the further fact that the leading truck wheels had to receive the shocks and blows delivered at each turn and irregularity of track, made the service as a whole so severe that it may well be compared with the service of chilled wheels under 50-ton capacity freight cars, the service of which rarely attains one-half of the speed in the case cited.

It is nevertheless true that wheel service at speeds of 25 to 30 miles per hour, especially on grades and in the case of long and heavy freight trains used in present practice, puts very severe strains upon the wheels with respect to the heating of tread and flange by brake friction. The result of this heating in connection with the quality of iron in the average chilled wheel with its high sulphur content, is the more rapid disintegration due to the fact that the metal is "red short," or "weak when hot," when heated, as all high-sulphur metal is.

The service of the same quality of chilled wheel under heavy freight locomotives may be noted from the statement annexed to this communication; and without going into a technical discussion of the matter it is clear from these and other cases which can be cited that chilled wheels have been made and can be made of such qualities of iron and other such methods of manufacture as will give efficient, safe, and economical service.

The subject at large has so many ramifications, and there are so many important details to consider, that it would not be possible to deal with it in any technical manner within the limits of a communication like the present one. It must be remembered that the number of car wheels in service is about 25,000,000, including all kinds and descriptions of car wheels in all kinds of service, steam, electric, etc.

Also that the output of wheels per day required to provide for renewals and repairs and average new construction is from 20,000 to 25,000 according to industrial and general business conditions.

from 6,000 to 8,000 tons of metal must be used per day to produce this product, and that in the case of chilled wheels at least 75 per cent. of this material is obtained by the reworking or recasting of wheels removed from service.

It must be remembered that the average load per wheel in steam locomotive service has practically doubled in the past 10 or 15 years, and that the operating and metallurgical problems arising out of this increase still remain to be dealt with in very large degree.

There is no doubt that a very considerable proportion of the wheels on freight cars under 40 and 50 ton capacity is in a condition that requires very serious and prompt attention. And there is little doubt that the manufacture of chilled wheels of the proper material, the proper analysis, and made under manufacturing conditions that will insure the fact that the necessary quality exists, before the wheels are placed in service, constitutes a very serious matter.

And it is not one to be entered upon without careful and due consideration for the present conditions of service and those that are likely to arise in the near future, nor without due regard for the means and facilities with which the present output of wheels is made. The problem involves primarily, the sufficient supply of the right kind of material, principally iron. Opinions may differ as to the quality of material that should be used, and no doubt it will be maintained by a considerable number of those interested that it is not necessary to use charcoal iron. It must be remembered in this connection that in 1895 the service of the chilled wheel was very satisfactory on the whole, and that it was made exclusively out of charcoal iron in those years prior to about 1890. The non-charcoal iron wheel as it has been used previously came into use about this time, and by 1895 the use of such wheels became dominating so far as the general demand was concerned. By 1900 the manufacture of charcoal iron wheels had practically terminated in this country, as indicated by the fact that the consumption of such iron by chilled wheel makers hardly amounted to 10 per cent. of the total weight of wheels made.

Nevertheless, whatever differences there may be in the opinions held by those concerned, the fact seems clear that the quality of chilled wheels as they have been used since 1900 has not been satisfactory. In ordinary cases, such a kind it might answer to "change the vogue," as it is said, and try some new kind of a mixture for chilled wheels that would not be more expensive than the present mixture, and would necessitate the small change in price that would have to be made if charcoal iron mixtures were used. Considering all the facts in the case, and the very serious responsibilities resting on all concerned, it

would seem to be wise to return, at least for the time being, to an order of practice that did produce satisfactory results in the past.

I believe the future of the chilled wheel depends almost entirely on such a change; and if the latter is to receive the serious consideration of a sufficient number of railroad officials, charcoal iron makers, and car wheel manufacturers, and the evidence of that fact appears to a sufficient extent, then it will be necessary to take up the technical questions involved in the manufacture, and to consider and present the changes that should be made in such manufacturing apparatus and practice to insure the desired result.

of 33-in. 650-lb. Special Charcoal Iron Wheels Under L. S. &  
R. R. Freight Locomotives, with Reason for their Removal.

| Cause.            | Mileage. | Cause.            | Mileage. | Cause.            |
|-------------------|----------|-------------------|----------|-------------------|
| Shell out.....    | 61,057   | Good.....         | 42,984   | Slid.....         |
| Shell out.....    | 61,057   | Slid.....         | 42,984   | Slid.....         |
| Shell out.....    | 49,373   | Good.....         | 64,203   | Worn out.....     |
| Shell out.....    | 49,373   | Sharp flange..... | 64,203   | Shell out.....    |
| Shell out.....    | 59,159   | Worn out.....     | 51,397   | Worn out.....     |
| Shell out.....    | 59,159   | Good.....         | 51,397   | Shell out.....    |
| Shell out.....    | 13,375   | Sharp flange..... | 49,544   | Worn out.....     |
| Shell out.....    | 13,375   | Good.....         | 49,544   | Shell out.....    |
| Sharp flange..... | 19,490   | Slid.....         | 45,771   | Sharp flange..... |
| Sharp flange..... | 19,490   | Sharp flange..... | 45,771   | Worn out.....     |
| Sharp flange..... | 52,071   | Shell out.....    | 42,984   | Worn out.....     |
| Sharp flange..... | 52,071   | Worn out.....     | 42,984   | Good.....         |
| Worn out.....     | 53,033   | Worn out.....     | 54,297   | Shell out.....    |
| Worn out.....     | 53,033   | Worn out.....     | 54,297   | Sharp flange..... |
| Sharp flange..... | 50,216   | Shell out.....    | 67,173   | Worn out.....     |
| Sharp flange..... | 50,216   | Shell out.....    | 67,173   | Worn out.....     |
| Worn out.....     | 68,995   | Shell out.....    | 60,316   | Worn out.....     |
| Worn out.....     | 68,995   | Worn out.....     | 60,316   | Worn out.....     |
| Worn out.....     | 67,776   | Shell out.....    | 68,955   | Worn out.....     |
| Worn out.....     | 67,776   | Worn out.....     | 68,955   | Worn out.....     |
| Sharp flange..... | 67,173   | Shell out.....    | 67,419   | Shell out.....    |
| Worn out.....     | 67,173   | Worn out.....     | 67,419   | Shell out.....    |
| Good.....         | 61,986   | Sharp flange..... | 64,203   | Shell out.....    |
| Sharp flange..... | 61,986   | Sharp flange..... | 64,203   | Shell out.....    |
| Good.....         | 61,642   | Shell out.....    | 68,955   | Worn out.....     |
| Worn out.....     | 61,642   | Worn out.....     | 68,955   | Worn out.....     |
| Worn out.....     | 68,255   | Shell out.....    | 62,181   | Worn out.....     |
| Worn out.....     | 68,255   | Worn out.....     | 62,181   | Shell out.....    |
| Worn out.....     | 75,265   | Worn out.....     | 48,887   | Worn out.....     |
| Worn out.....     | 75,265   | Worn out.....     | 48,887   | Sharp flange..... |
| Good.....         | 61,986   | Sharp flange..... | 42,984   | Slid.....         |
| Good.....         | 61,986   | Shell out.....    | 42,984   | Worn out.....     |
| Worn out.....     | 67,173   | Worn out.....     | 59,369   | Good.....         |
| Worn out.....     | 67,173   | Worn out.....     | 59,369   | Shell out.....    |
| Sharp flange..... | 61,986   | Sharp flange..... | 59,372   | Sharp flange..... |
| Sharp flange..... | 61,986   | Shell out.....    | 59,372   | Shell out.....    |
| Sharp flange..... | 41,855   | Good.....         | 61,322   | Sharp flange..... |
| Worn out.....     | 41,855   | Worn out.....     | 61,322   | Sharp flange..... |
| Worn out.....     | 67,419   | Sharp flange..... | 61,322   | Sharp flange..... |
| Worn out.....     | 67,149   | Worn out.....     | 61,322   | Worn out.....     |
| Sharp flange..... | 62,181   | Worn out.....     | 61,322   | Worn out.....     |
| Worn out.....     | 62,181   | Worn out.....     | 61,322   | Shell out.....    |
| Good.....         | 64,203   | Shell out.....    | 48,867   | Good.....         |
| Worn out.....     | 64,203   | Shell out.....    | 48,867   | Good.....         |
| Worn out.....     | 58,912   | Shell out.....    | 48,867   | Sharp flange..... |
| Worn out.....     | 48,912   | Worn out.....     | 48,867   | Sharp flange..... |
| Worn out.....     | 70,722   | Worn out.....     | 117,455  | Worn out.....     |
| Good.....         | 70,722   | Worn out.....     | 117,455  | Worn out.....     |
| Slid.....         | 75,518   | Worn out.....     | 112,258  | Worn out.....     |
| Worn out.....     | 72,297   | Worn out.....     | 109,158  | Worn out.....     |
| Sharp flange..... | 72,297   | Shell out.....    | 113,217  | Worn flat.....    |
| Worn out.....     | 85,933   | Worn out.....     | 118,015  | Worn flat.....    |
| Slid flat.....    | 85,933   | Worn out.....     | 103,273  | Worn out.....     |
| Slid flat.....    | 83,431   | Worn out.....     | 127,191  | Worn out.....     |
| Slid flat.....    | 83,431   | Shell out.....    | 127,191  | Worn out.....     |
| Slid flat.....    | 80,486   | Worn flat.....    | 137,005  | Worn out.....     |
| Worn out.....     | 83,897   | Worn out.....     | 137,405  | Worn flat.....    |

*33-in. Wheels.—Continued.*

| Mileage. | Cause.            | Mileage. | Cause.            | Mileage. | Cause.           |
|----------|-------------------|----------|-------------------|----------|------------------|
| 66,391   | Worn out.....     | 77,709   | Sharp flange..... | 82,355   | Worn out.....    |
| 43,859   | Good.....         | 77,709   | Worn out.....     | 79,828   | Shell out.....   |
| 43,859   | Worn out.....     | 86,719   | Worn out.....     | 86,285   | Worn out.....    |
| 66,381   | Worn out.....     | 86,719   | Sharp flange..... | 86,282   | Worn flange..... |
| 66,391   | Worn out.....     | 68,622   | Worn out.....     | 91,821   | Worn out.....    |
| 66,391   | Shell out.....    | 68,622   | Worn out.....     | 68,677   | Worn out.....    |
| 66,391   | Shell out.....    | 80,725   | Worn out.....     | 67,802   | Worn out.....    |
| 59,372   | Sharp flange..... | 80,725   | Worn out.....     | 104,218  | Worn out.....    |
| 59,372   | Worn out.....     | 80,725   | Worn out.....     | 110,160  | Worn out.....    |
| 58,410   | Worn out.....     | 80,725   | Worn out.....     | 110,160  | Worn out.....    |
| 58,410   | Good.....         | 85,822   | Worn out.....     | 96,405   | Worn out.....    |
| 62,934   | Worn out.....     | 85,822   | Worn out.....     | 96,405   | Worn out.....    |
| 62,934   | Worn out.....     | 93,158   | Shell out.....    | 93,700   | Worn out.....    |
| 46,723   | Sharp flange..... | 93,158   | Worn flange.....  | 93,700   | Worn out.....    |
| 46,723   | Good.....         | 86,468   | Worn flat.....    | 103,576  | Worn out.....    |
| 39,860   | Slid.....         | 82,807   | Shell out.....    | 103,576  | Worn flat.....   |
| 39,860   | Slid.....         | 83,613   | Worn flat.....    | 98,901   | Worn out.....    |
| 39,860   | Slid.....         | 83,613   | Shell out.....    | 98,901   | Worn out.....    |
| 54,263   | Good.....         | 83,613   | Worn out.....     | 110,183  | Worn out.....    |
| 54,263   | Worn out.....     | 83,613   | Worn flange.....  | 110,183  | Worn out.....    |
| 59,372   | Good.....         | 83,613   | Worn out.....     | 107,600  | Worn out.....    |
| 59,372   | Good.....         | 100,180  | Worn flange.....  | 107,600  | Worn out.....    |
| 59,372   | Sharp flange..... | 100,180  | Worn out.....     | 110,827  | Worn out.....    |
| 59,372   | Shell out.....    | 82,481   | Worn out.....     | 110,827  | Worn out.....    |
| 77,709   | Shell out.....    | 82,481   | Worn out.....     | 121,857  | Worn out.....    |
| 77,709   | Shell out.....    | 100,883  | Worn out.....     | 121,857  | Worn out.....    |
| 77,709   | Sharp flange..... | 100,883  | Worn out.....     | 121,857  | Worn out.....    |
| 77,709   | Worn out.....     | 82,355   | Worn out.....     |          |                  |



## Valuation of Iron-Mines.

discussion of the paper of James R. Finlay, presented at the New York Meeting, May, 1913, and printed in *Bulletin* No. 75, March, 1913, pp. 487 to 502; see also in No. 77, May, 1913, pp. 915 to 940.

BRINSMADE, Puebla, Puebla, Mexico (communication to the  
y\*):—As I have previously considered the general equations  
e-valuation,<sup>1</sup> I will here discuss only that part of Mr. Finlay's  
criticized by E. E. White, along with some of the general prin-  
mining taxation, under the following six topics:

te of interest earned by sinking-fund.

te of interest earned by investment.

ace of royalty item in valuation.

ace of taxation item in valuation.

alculation of future ore-prices.

valuation of undeveloped mining land.

*Rate of Interest Earned by Sinking-Fund.*—Mr. Denny's quoted  
of a 3 per cent. rate is evidently based on English conditions  
he Boer war. The great destruction of liquid capital by the  
ars and catastrophes since 1897, along with the flood of gold  
sequent rise in the average index of commodity prices, has  
edly increased the rate of interest at least one-half per cent.  
United States sound savings banks now allow 4 per cent. on  
, while safe bonds are quoted at prices which yield even 5

*Rate of Interest Earned by Investment.*—Gold-mines with uncertain  
ty ore reserves, the objects of Mr. Denny's quoted remarks,  
e different from iron, copper, or coal mines with definite  
reserves blocked out ahead by drilling or driving. While  
cent. is often an inadequate yield from gold-mines, the latter  
mines are often as safe as city real estate and resemble it as  
tment in more ways than one.

real estate is also speculative, for a shifting of the favorite  
for wholesale or retail trade will mean a corresponding  
in the value of any included building lot. Yet 5 per cent.  
he common rate used by agents in figuring the value of a  
iness lot of a given rental yield. The investing public is evi-

\* Received Aug. 2, 1913.

<sup>1</sup> Calculation of Mine-Values, *Trans.*, xxxix, 243 (1908).

dently satisfied with a net yield around 5 per cent. from Michigan mines, for during many years the stock of the Calumet & Hecla Co. has been often quoted at prices to yield only 7 per cent., and this includes the necessary sinking-fund annuity.

3. *Place of Royalty Item in Valuation.*—As a mining royalty is equivalent economically to the ground rent of a building lot, Mr. White's idea of adding the royalty to the mining cost, thus subtracting it from the profits figure used to reckon valuation, would be the same as exempting the land-value of the mine from taxation.

City property is valued for taxation by capitalizing the total rent, which includes both ground rent and the hire of the buildings and improvements. The only difference for mine-valuation then should be the subtraction of an annuity item (to atone for the exhaustion of the mineral land-value) from the net operating profit in order to get the sum corresponding to the total rent of city real estate, which is capitalized for the assessment valuation.

In my recent discussion<sup>2</sup> of Dr. Raymond's article I have shown by means of the trinitarian diagram of economics that rent is a residual factor, obtained by subtracting wages and interest from the total output, and therefore cannot under ordinary competitive conditions enter into the fixing of prices. Mr. White, by adding the royalty, or land-rent, item to the mining cost is thus cherishing the illusion that royalty is a factor *necessarily* affecting the scale of prices of his competitors, instead of being merely the deduction which some fee owners are able to make from the net operating profit.

4. *Place of Taxation Item in Valuation.*—Again referring to practice in city real estate, we find that the *current* taxes are deducted from the gross total rent in order to get the net total rent used as the basis of valuation. Mr. White's criticism here is evidently valid, but, owing to the varying rates of ore production, I believe his method, of adding the tax item to the mining cost, is less practical than to figure the rate of taxation in the equation for present worth of \$1, as suggested below.

Let  $V$  = value or present worth of a \$1 dividend to be assessed by taxation.

$a$  = annuity to be paid to sinking-fund.

$r$  = rate of interest earned on sinking-fund.

$R$  = rate of interest earned on investment.

$t$  = current rate of taxation.

$n$  = number of years dividend is to be earned.

<sup>2</sup> Our National Resources and Our Federal Government, *Bulletin* No. 77, May, 1913, p. 971.

by suggested system  $\$1 = (R + t) V + a$  (A)

from algebra  $a = \frac{Vr}{(1 + r)^n - 1}$  (B)

substitute in (A) the value of  $a$  in (B) and

$$1 = (R + t) V + \frac{Vr}{(1 + r)^n - 1} \quad (C)$$

using (C) for  $V$  and

$$V = \frac{1}{R + t + \frac{r}{(1 + r)^n - 1}} \quad (D)$$

in equation (D) the system of Mr. Finlay gives us  $R$  and  $r$ , while  $t$  is assumed approximately for the preliminary calculation. When a preliminary valuation of Michigan has been made the current  $t$  can be calculated directly from the necessary budget. With the correct figure for  $t$  it is easy to get the correct figure for  $V$  by using equation (D) a second time.

*Calculation of Future Ore-Prices.*—Mr. White seems to me unnecessarily worried over Mr. Finlay's assumed future base of \$4.50 for iron-ore. As Mr. Finlay hints on p. 75 of his original there is no reason why mining property should not be re-assessed annually by his system, as is everywhere the American customary real estate. Any erroneous assumption of the future ore or cost of mining will thus only affect taxation for the year. Another advantage of annual re-assessments would be that the ore sold and the ore discovered in the previous year would be reckoned in the revaluation.

*Valuation of Undeveloped Mining Land.*—On p. 12 of his original Mr. Finlay says of undeveloped mining land that "no definite appraisal can be made." Here I differ, for a definite appraisal must be made if speculation and the hamstringing of development are to be discouraged. The most practical method of appraisal seems to be "annual assessment," under which the land-owner sets his own value, subject to the safeguard of the State's right to purchase during the year at the assessed value. A similar plan has been suggested by E. B. Kirby.<sup>4</sup>

### Summary.

The sustaining of Mr. Finlay's general scheme of mine-valuation in the Michigan courts marks such an advance in the equitable taxation of mines as did the Ford franchise-tax law of New York in the

*Valuation of Michigan Mining Properties*, by State Board of Taxation (1911).

*Principles of Mine Taxation*, *Engineering and Mining Journal*, vol. xcii, No. 18, Oct. 28, 1911).

taxation of public utilities. The fact that State assessing officials have usually been either incompetent or corrupt accounts for the previous under-assessment of mines and public utilities as compared with farms and homes.

The present trend in such progressive and democratic countries as Great Britain, Germany, and the self-governing British colonies is toward placing the entire cost of government on land-value owners, because they are the only class who financially benefit from government activity, since they absorb the individually unearned increment from natural resources. The reform is best effected practically by gradually exempting true capital (buildings, improvements, etc.) from taxation and correspondingly increasing the tax rate on land values. This new system is explained generally by T. G. Shearman in *Natural Taxation* and for mining by an article<sup>5</sup> I published in 1909.

The increase in the valuation of Michigan mines may be unfortunate for any operators who, disregarding the advancing democratization of taxation, were unwise enough to take long leases on a fixed royalty with the proviso that the lessee should pay all taxes, but even these may console themselves with the thought that Michigan improvements are not yet exempt from taxation.

By Mr. Finlay's system, the mine whose ore is produced at a loss is valued at nothing, even though its surface equipment may have cost a large sum, as in the case of many of the Michigan copper-mines. This system is indeed beneficial to producers, for improved mines are thus exempt from taxation until they become profitable; but is it not most discordant with the accepted theory of the general property tax? On the same principle, should not unprofitable buildings or machinery in other industries, such as manufacturing or commerce, be also called worthless and exempt from taxation? What a fortunate occurrence, if the controversy over Mr. Finlay's valuations results in a public exposure of the absurdity of the general property-tax system for a community of democratic producers!

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<sup>5</sup> *Natural Taxation of Timber and Mining Land*, *Mining World*, vol. xxxi, No. 21, p. 1023 (Nov. 20, 1909).

## Sulphide Ores of Copper. Some Results of Microscopic Study.

of the paper of L. C. Graton and Joseph Murdoch, presented at the New York Meeting, February, 1913, and printed in *Bulletin* No. 77, May, 1913, pp. 741 to 797.

AS T. READ, New York, N. Y. (communication to the Secretary).—At the meetings of English technical societies it not infrequently happens that, during the discussion of a paper, someone will say that although he highly appreciated the material presented nevertheless he believed it would have been better if some phase of the question had been more highly emphasized. As a result of that this form of discussion is permissible in the Institute, I like to reiterate the point made by Prof. A. J. Moses that the best proof of the identity of the minerals in question is an essential feature of the study of ores in this way. This is also expressed by Krusch in his recent valuable paper<sup>1</sup> on the sulphide ores in which he arrives at conclusions diametrically opposed to those of Graton, as follows: "The diagnostic properties of the various minerals are known to but a limited circle of investigators." Earlier investigators began the study of ores beneath the microscope by reflected light, but discontinued their work, in most cases, because they were unwilling to undertake the great amount of preparatory work necessary to securely establish a basis for their inference. It is evident that Messrs. Graton and Murdoch realize that the unpublished later paper on diagnostic characters will be the more important of the two, but the point should be emphasized to forestall the publication of literature from other investigators who may gain the impression that the brief survey of polished specimens is a *vade mecum* of incontrovertible conclusions as to any given ore deposit.

In the 750 of this paper the statement is made that the great volume of laboratory study has prevented a corresponding study of the literature on the subject. This doubtless serves to explain the footnote on page 741 where only the recent paper by A. C. Spencer is cited as corroborating the view that secondary enrichment is essentially a process of enrichment. In the *Transactions* for 1906<sup>2</sup> I stated the following

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Received Sept. 25, 1913.

*Mining and Scientific Press*. vol. cvii, No. 11, pp. 418 to 423 (Sept. 13, 1913).

*Trans.*, xxxvii, 302 (1906).

conclusion from a chemical study of enrichment. "It is clear, then, that oxidation alone is sufficient to produce the enriched sulphides occurring in the zone of secondary enrichment." The fact that the chemical work on which this conclusion was based was somewhat faulty does not detract from the soundness of the conclusion, and it is the more gratifying to find it substantiated by other methods of work. While believing that oxidation has been more important than reduction in the formation of the rich secondary sulphides, it is probable that the latter is at times important. The distinction Krusch and others make between oxidation and cementation ores may at times be of service, though in others it is unquestionably a source of added confusion, unless the term cementation is strictly defined. The appearance of two such important papers in quick succession is pleasing evidence that the study of these important and puzzling ores is being followed with unabated vigor.

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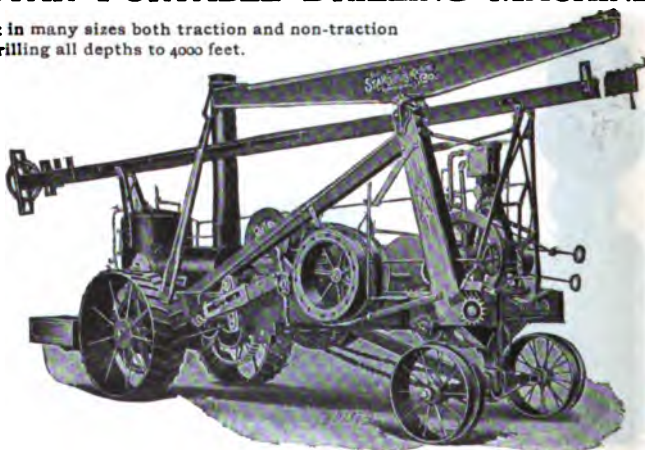
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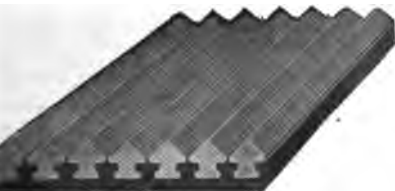
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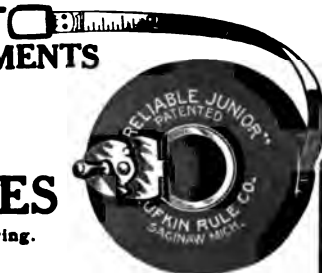
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## ARTICLE II.—MEMBERS.

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SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely: as Members, all professional mining engineers, geologists, metallurgists, or chemists, and all persons actively engaged in mining and metallurgical engineering, geology, or chemistry; as Associates, all persons desirous of being connected with the Institute who in the opinion of the Board of Directors are suitable.

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# Bulletin of the American Institute of Mining Engineers.



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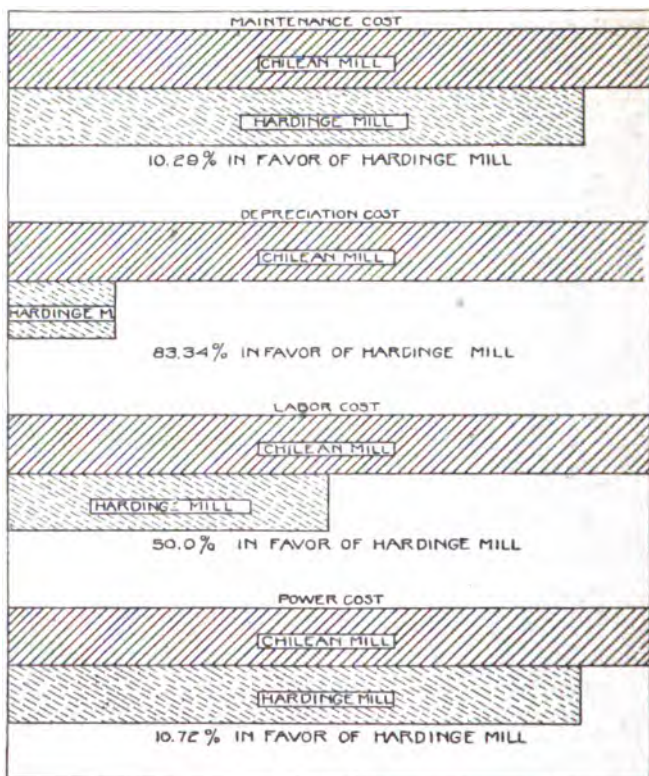
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COMPARISON OF COSTS

HARDINGE MILLS VS. CHILE MILLS



# 1,275,000

**TONS OF ORE  
GROUND IN ONE TEST**

THIS TEST IS FULLY EXPLAINED IN A PAPER BY MR. R. FRANKE, PRESENTED TO THE A. I. M. E. AT BUTTE. WE WOULD BE GLAD TO SEND YOU A COPY.

**HARDINGE CONICAL MILL CO.  
50 CHURCH STREET  
NEW YORK**

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Halharding, New York

Sales Agents for Montana, Nevada, Idaho, Utah—Mine & Smelter Supply Co., Salt Lake City, Utah.

Colorado, Wyoming, N. Mexico, So. Dakota—Hendrie & Bolthoff Mfg. & Supply Co., Denver, Colo.

# Announcement.

AMONG the many actions for the general good which members of the Institute can perform, the securing of desirable new members is the most important. Every society derives its strength from its unity of purpose and personnel. The Institute should include in its membership every man whose work in mining, metallurgy, or related fields, qualifies him to become a member, and the more fully it attains this ideal the greater its influence will be. At present many such men are not members and this committee has been formed to remedy, if possible, this defect. The most effective work can be done by individual members, rather than by committees. Each member knows the man who is qualified to become a member of the Institute but has never joined. Send him the attached proposal blank, with a cordial invitation to apply for membership.

## Committee on Increase of Membership.

ADOLPHE E. BORIE, *Chairman.*

THOMAS T. READ, *Secretary*, Woolworth Bldg., New York, N. Y.

### *Vice-Chairmen.*

JOHN H. ALLEN,  
RICHARD M. ATWATER, JR.,  
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A. CHESTER BEATTY,  
J. PARKE CHANNING,

GEORGE M. COLVOCORESSES,  
ROBERT PEELE,  
CHARLES P. PERIN,  
JOSEPH A. VAN MATER,  
ARTHUR L. WALKER.

Bard,  
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E. C. Branner,  
Er Carter,  
J. Clark,  
Corning,  
abtree,  
E. G. Crawford,  
Davidson,  
D'Invilliers,  
S. Douglas,  
er Douglas,  
ard N. Eavenson,  
ard Eckfeldt,

R. C. Gemmell,  
F. Louis Grammer,  
Ernest A. Hersam,  
Edwin C. Holden,  
William L. Honnold,  
Reginald E. Hore,  
Tedashiro Inouye,  
C. Colcock Jones,  
Eugene P. Kennedy,  
Chester F. Lee,  
Richard S. McCaffery,  
James F. McClelland,  
Milton H. McLean,  
Philip N. Moore,

T. H. O'Brien,  
James J. Ormsbee.  
Edward W. Parker,  
John B. Porter,  
F. Danvers Power,  
R. M. Raymond,  
Robert H. Richards,  
LeRoy Salsich,  
Henry Lloyd Smyth,  
F. W. Traphagen,  
Elton W. Walker.  
Cho Yang,  
Morrison B. Young.





AMERICAN INSTITUTE OF MINING ENGINEERS

29 West 39th Street, New York, N. Y.

PROPOSAL FOR MEMBERSHIP

(Name in Full)

tion

ss

by proposed by the undersigned, as a

American Institute of Mining Engineers.

Signatures of three  
Members or  
Associates.

birth Year of birth

on, general and technical, when, where and how acquired,  
with degrees, if any.

rs

[illegible]

\_\_\_\_\_  
Signature

**EXTRACTS FROM THE CONSTITUTION.**

ARTICLE II.—MEMBERS.

Institute shall comprise four cl

SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely:

As Junior Members, all students in good standing in engineering schools who have not taken the degrees and who are nominated by at least two of their instructors. \* \* \*

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# BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.

3

NOVEMBER

1913

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PUBLISHED MONTHLY

BY THE AMERICAN INSTITUTE OF MINING ENGINEERS  
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Entered as second class matter, October 16, 1911, at the post office at Philadelphia, Pa., under the Act of March 3, 1879.

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## NOMINATIONS FOR OFFICERS.

In accordance with the Constitution, Article VII., the following nominations have been prepared by the Nominating Committee, submitted to the Board of Directors at its October meeting, and are hereby published for the information of the members.

|                                    |                              |    |
|------------------------------------|------------------------------|----|
| For Director and President:        | Benjamin B. Thayer, District | 0  |
| For Directors and Vice-Presidents: | Herbert C. Hoover, District  | 6  |
|                                    | W. L. Saunders, District     | 0  |
| For Directors:                     | Reginald W. Brock, District  | 11 |
|                                    | Charles W. Merrill, District | 6  |
|                                    | Albert R. Ledoux, District   | 0  |
|                                    | Henry L. Smyth, District     | 1  |
|                                    | D. C. Jackling, District     | 7  |

The Constitution further provides that "Any complete or partial ticket nominees signed by any twenty-five Members or Associates of the Institute and transmitted to the Secretary by December 15 shall also be printed and circulated with the official ticket and over the names and with the recommendations of the nominators, together with an expression of opinion of the Board thereon if deemed expedient."

**NEW BOOKS ON MINING, METALLURGY, GEOLOGY, ETC.**

We call the attention of our members to a change in the Library Announcements, with the object of keeping the members currently informed of new books on subjects in which they are interested. The Library is glad to furnish members at any time with a list of the best reference or text books on particular subjects, and we again remind all members of the research work of the Library in providing indexes, abstracts, translations, and other data on special subjects.

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**LAST CALL FOR DUES.**

The attention of members is called to Article III. of the Constitution, which provides that unless dues are paid by or before the first day of May of each year, the *Bulletin* shall no longer be sent to the member in arrears. As members are frequently absent in the field, and do not receive their notices from this office, they are reminded at this early date that any future inconvenience may be spared them.

Members are also reminded that the provisions of the new Constitution, whereby a man ceases to have the privileges of membership when he is in arrears of dues for one year, become operative on Jan. 1, 1914. This provision will be strictly enforced.

---

**BOARD OF DIRECTORS.**

*Meeting, Oct. 24, 1913.*—The sum of \$1,250 was directed to be sent to the International Engineering Congress, 1915, in accordance with the terms of the Institute's guarantee.

It was voted to request the several Technical Committees to recommend names of their members as sub-chairmen and members of sub-committees to co-operate with the Bureau of Mines.

The Finance Committee was empowered to send all members in arrears a notice that the provisions of the Constitution, by which they cease to hold the privileges of membership if their dues are not paid by Jan. 1, 1914, become operative on that date, unless the Directors vote to extend the time in each individual case.

The report of the Nominating Committee, printed on page i, was accepted.

It was voted that a notice to be prepared by the Committee on Increase of Membership and an application blank for membership be printed in the front of each *Bulletin*.

The report of the Committee on Patent Law Legislation was adopted and the Committee discharged.

The Budget of the Chairman and the Secretary-Treasurer of the Colorado Local Section for the balance of the present calendar year was accepted and an appropriation of \$47.75 made to them.

Upon the nomination of two members of the Committee on Honorary Members, backed by 13 members of the Institute who are not members of the Board of Directors, Dr. Frank Dawson Adams, of Canada, was unanimously elected an Honorary Member of the Institute.

Upon the nomination of two members of the Committee on Honorary Members, backed by 11 members of the Institute who are not members of the Board of Directors, Mr. Ezequiel Ordoñez, of Mexico, was unanimously elected an Honorary Member of the Institute.

## EMMONS VOLUME ON ORE-DEPOSITS.

*A continuation of the "Posepny" Volume.*

prising papers descriptive of ore-deposits and discussions of their edited, with an introduction, by Dr. S. F. Emmons. The volume is also a Biographical Notice of Dr. Emmons by his associate and Dr. George F. Becker, and a comprehensive Bibliographical Index Science of Ore-Deposits, prepared by Prof. John D. Irving, of the Scientific School of Yale University. Dr. Emmons had finished editorial work and written his Introduction before his lamented death; and the Volume contains his last words upon the subject to which given the work of his life, and on which he was justly regarded as most authority.

*Contents.*

Certain Ore-Deposits. By S. F. EMMONS.  
 Relations of Ore-Deposits. By S. F. EMMONS.  
 Distribution of the Useful Metals in the United States. By S. F. EMMONS. Discussion, by A. CHURCH, ARTHUR WINSLOW, S. F. EMMONS, and WILLIAM HAMILTON MERRITT.  
 Theory of Joints. By GEORGE F. BECKER. Discussion, by H. M. HOWE, R. W. RAYMOND, C. R. and GEORGE F. BECKER.  
 n of Gold. By HENRY LOUIS.  
 Alteration of Ore-Deposits. By R. A. F. PENROSE, JR.  
 es of Rosita and Silver Cliff, Colorado. By S. F. EMMONS.  
 Certain Auriferous Lodes. By JOHN R. DON. Discussion, by JOSEPH LE CONTE, S. F. EMMONS, BECKER, ARTHUR WINSLOW, W. P. BLAKE, and J. R. DON.  
 of Country-Rock on Mineral Veins. By WALTER HARVEY WEED.  
 ecks and Circulating Waters as Factors in Ore-Deposition. By J. F. KEMP.  
 on of Igneous Rocks and Their Segregation or Differentiation as Related to the Occurrence a. By J. E. SPURR. Discussion, by A. N. WINCHELL.  
 of Ore-Deposition. By WALTER F. JENNEY. Discussion, by JOHN A. CHURCH.  
 ts near Igneous Contacts. By WALTER HARVEY WEED. Discussion, by W. L. AUSTIN.  
 on of Vein-Enrichment by Ascending Hot Waters. By WALTER HARVEY WEED.  
 ones as Guides to Ore-Deposits in the Cripple Creek District, Colorado. By E. A. STEVENS.  
 Features of the Gold-Production of North America. By W. LINDGREN. Discussion, by W. LER and W. L. AUSTIN.  
 a Factor in Ore-Formation. By HALBERT POWERS GILLETTE.  
 ts of Sudbury, Ontario. By CHARLES W. DICKSON.  
 the Copper-Deposits of Clifton-Morenci, Arizona. By W. LINDGREN.  
 posits at San Jose, Tamaulipas, Mexico. By J. F. KEMP.  
 Origin of Vein-Forming Waters in Southeastern Alaska. By A. C. SPENCER.  
 lations of the Western Nevada Ores. By J. E. SPURR.  
 uarts Veins of Silver Peak, Nevada, the Result of Magmatic Segregation? By J. B. HASTINGS  
 e of Stibnite at Steamboat Springs, Nevada. By W. LINDGREN.  
 of Lake Superior Geology with Special Reference to Recent Studies of the Iron-Bearing  
 By C. K. LEITH.  
 Relations of the Scandinavian Iron-Ores. By H. SJÖGREN.  
 and Enrichment of Ore-Bearing Veins. (With Supplementary Paper.) By GEORGE J. OPT.  
 on of the Elements in Igneous Rocks. By H. S. WASHINGTON.  
 Manganese in the Superficial Alteration and Secondary Enrichment of Gold-Deposits of lited States. By W. H. EMMONS.  
 apers.  
 hy of the Science of Ore-Deposits. By J. D. IRVING, H. D. SMITH, and H. G. FERGUSON.  
 volume contains 1002 pages. Price, bound in cloth, \$5; in half o, \$6. Both the Emmons and the Posepny Volumes on Ore- is, bound in cloth, \$8; in half morocco, \$10.

READY FOR DISTRIBUTION.

## THE INSTITUTE FORUM.

### *Maps and Mining Data for the Library.*

I suggest that the Institute Library can increase its usefulness by systematically soliciting from the engineers and mining companies all published reports and maps, and parts of reports and records, not of a private or confidential nature. If this is done an engineer assigned to report on a well-known property or district may depend on finding at the library a large amount of preliminary data and general information from these official and engineering reports relating to his prospective investigation.

In many mining reports a large part of the report is of a general technical and scientific character, and there could be no good objection on the part of either the engineer or his client to making such information thus of record. I believe there would be a great deal of information furnished by the engineers if they were properly solicited under this plan.

I have found on different occasions that much work could be saved by such records now in the Library.

The plan would also have the advantage of keeping the Library in closer touch with the active engineers, a feature to be desired.

I also have in mind that the Library should undertake to collect all the prospectuses and financial literature which is issued in connection with mining. Of course a great deal of this is unreliable, but even this is valuable for record in the matter of legal and other investigations.

I shall be glad to co-operate with you, and do anything I can to develop more in detail the general ideas above noted.

Yours very truly,  
KIRBY THOMAS.

NOTE.—The Library of the Institute makes a specialty of collecting and filing material of this character, and the letter printed above is brought to the attention of members in the hope that they will co-operate by sending in copies of maps, reports of properties, etc.

### *Descriptive Names for Methods and Processes.*

I suggest that the Editing Committee make an attempt to restrict the growing practice of calling methods and processes after their author or inventor.

The principle of the process usually has a simpler name than the author, and this name has the further advantage of conveying information as to the process itself.

Out of a large number of examples I have selected a few which I hope will make my meaning clear:

The Leyner cut becomes the center cut, or the square cut.

The Anaconda set becomes the side-pressure set.

The MacArthur-Forrest process becomes the cyanide process.

The Diehl process becomes the bromo-cyanide process.

The Clancy process becomes the electro-cyanamid process.

The Ilgner set becomes the fly-wheel motor-generator set.

The Ward-Leonard control becomes the variable-voltage control.

If we can simplify and increase efficiency of thought by concerted action, the industry will be an immediate gainer thereby.

Yours truly,  
WILLIAM R. CHEDREY.

# PERSONAL.

(Members are urged to send in for this column any notes of interest concerning themselves or their fellow-members.)

Members and visitors who registered at Institute headquarters during October:

Wesley, St. Petersburg, Russia.  
 ... Washington, D. C.  
 Clark, Lead, S. D.  
 ...winson-Lessing, St. Petersburg.  
 ... Gillespie, Abangarez, Costa Rica.  
 ... Talcott, Irvington-on-Hudson, N. Y.  
 ... Woodbridge, Duluth, Minn.  
 ... Fyfe, Boston, Mass.  
 ... Seip, Wilkes-Barre, Pa.  
 ...land, Boston, Mass.  
 ...yre, Brewster, N. Y.  
 ...auveur, Cambridge, Mass.  
 ... H. Leach, Brockton, Mass.  
 ...oslie, Kristiania, Norway.  
 ... A. Wong, Honolulu, Hawaii.

Charles W. Merrill, San Francisco, Cal.  
 Carl J. Trauerman, Butte, Mont.  
 Herbert B. Cox, Boston, Mass.  
 James W. Malcolmson, Kansas City, Mo.  
 A. E. Sunderhauf, Paramaribo, Dutch Guiana, S. A.  
 D. W. Brunton, Denver, Colo.  
 A. P. Watt, Newark, N. J.  
 S. A. Taylor, Pittsburgh, Pa.  
 Ralph Wilcox, Miami, Ariz.  
 William J. Cox, Denver, Colo.  
 E. P. Ross, Duquesne, Pa.  
 H. Mortimer-Lamb, Montreal, Canada.  
 F. L. Grammer, Leesburg, Va.  
 R. R. Moore, Mexico City, Mex.  
 Charles E. van Barneveld, San Francisco, Cal.

T. Reid has been appointed Consulting Engineer and General Manager of the Buffalo Valley Gold Mining & Leasing Co.'s mines at Nevada.

H. Weld, A. B., S. M., has opened an office at 66 Broadway, New York, N. Y., and is prepared to undertake geological and engineering examinations of mines and mineral properties, with a view to their extension, valuation, development, equipment, or economical management operation.

J. Eye has been appointed Superintendent for the Imperial Reduction, at Ogilby, Cal.

J. Dickman, mining engineer, now engaged upon the examination of iron and coal properties in Western Canada, has become associated with Robert W. Hunt & Co., in the United States, and with Robert W. ... Co., Ltd., in Canada.

J. Patterson, Jr., has been appointed Mine Superintendent for the ...-American Iron Co., at Felton, Cuba.

J. R. Whitaker is Consulting Engineer for the Canadian Agency, New York, which has recently acquired the Bonanza mine in ...

J. Ross has accepted a position with the Carnegie Steel Co., at the Thomson works.

Charles E. van Barneveld, who is in charge of the Mining and Geological Exhibit of the Panama-Pacific Exposition, will be in the ... during the coming month on business for the Exposition. His headquarters will be at the Members' Room of the Institute, where he may be ...

W. H. Graham has been appointed Professor of Mining Engineering at Nova Scotia Technical College at Halifax.

W. H. Sweetser, President of the Thomas Iron Co., Easton, Pa., has been elected President of the Ironton railroad, a subsidiary of the ... Iron Co.

J. Smith has recently been appointed Chief Technical Assistant to the General Manager of the Lena Goldfields, Ltd., Bodaibo, Siberia.

**Charles E. Hulick** has been appointed Superintendent of the Thomas Iron Co.'s furnaces at Hokendauqua.

**A. E. Borie** has resigned as Vice-President of the Taylor-Wharton Iron & Steel Co., and has been elected Chairman of the Board of Directors.

**W. L. Kluttz** has accepted a position as Vice-President and General Manager of the Central Iron & Coal Co., Tuscaloosa, Ala.

**W. C. McKee** resigned his position as Superintendent of Blast Furnaces of the Inland Steel Co., Indiana Harbor, Ind., to become General Superintendent of the Thomas Iron Co.'s blast-furnace plants at Hokendauqua, Hellertown, Alburtis, and Island Park, Pa., with headquarters at Hokendauqua.

---

### POSITIONS VACANT.

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Position in sales department is open for a mining engineer with experience in mine ventilation and possessing some knowledge of fan design; one competent to lay out ventilating systems to meet various conditions. No. 2.

A large company manufacturing mining machinery has an opening in one of its Western agencies for a young mechanical engineer who has had some experience in designing along general machine shop lines, and who is familiar with cost systems. No. 3.

A large university desires to secure a prominent metallurgist for a vacant professorship in metallurgy. No. 4.

Opening at a mine in New Jersey for a technical graduate to begin work as chainman on the surveying squad. Salary \$50 per month to start. No. 5.

---

### ENGINEERS AVAILABLE.

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Member, graduate of College of Mines of University of California, with 12 years' operating experience in mining and milling in California, Canada, and Mexico, is open for engagement. Speaks Spanish fluently. No. 17.

Mining engineer and metallurgist open for engagement Jan. 1 as superintendent of mines or constructing engineer. Technically educated, with 14 years' experience in United States and Latin America in concentration, amalgamation, cyaniding, constructing. At present building large modern all-sliming cyanide mill in Central America. No. 18.

Member, mining and metallurgical engineer, is open to engagement. Specialty, the treatment of copper ores. Nine years' experience in the operation and also in the design and erection of copper smelteries. Four years true pyrite smelting. Able to organize the administration, accounting, etc., of a large plant. Speaks a fair amount of Spanish, Russian, German, and French. Qualified to take charge of a large smeltery, or to act as assistant to manager of a combined mining and smelting concern. No. 19.

Graduate of Pennsylvania State College, 30 years old, with experience



smelting, copper mining and smelting, assaying, mine sampling, gold milling and cyaniding, also as professor of metallurgy, is open for an opening. No. 20.

Member, technical graduate, 33 years old, 11 years' experience as chemistallurgist, and superintendent of lixiviation plant and in charge of operation of cyanide mill, is open for engagement. Speaks Spanish.

Graduate of Columbia School of Mines, with several years' mining and smelting (including cyaniding) experience, desires position as assistant in office of consulting engineer. Salary moderate. No. 22.

Member, with technical education, desires position as representative in the Middle West of a machinery or electrical supply house. No. 23.

Member, graduate mining engineer, with experience as mining and metallurgical engineer and as mine manager, is open for engagement. No. 24.

Member, lately with the Bishop Creek Milling Co., California, is now open for engagement as mine superintendent or superintendent of construction of mine and mill structures. No. 25.

Blow-converter operator, with several years' experience in the operation of steel castings, is open for engagement. No. 26.

Member, 42 years of age, with 25 years' experience as engineer and superintendent of mines, will be open for engagement Dec. 1. Experience in all branches of mining. Has handled large and small operations. No. 27.

Member, graduate engineer, age 35, with 15 years' practical experience in mining and railroad work, at present assistant manager and chief engineer of a large mining company, is desirous of locating convenient to schools for his children. No. 28.

Member, technical graduate, with 10 years' experience in metal mining in Mexico, two years in talc mining and one year in iron mining in the United States, is open for engagement. No. 29.

Engineer, aged 30 years, with 10 years' experience in coal mining and underground work, is open for engagement. Familiar with mine surveys and cost estimates. No. 30.

Member, graduate of McGill University in mechanical engineering, with several years' experience in mining mica, gold, silver and copper in Ontario and the West, and in hydraulicking in Alaska, is open for engagement. Four years as engineer for a steel construction company. No. 31.

Blow-converter blower, with several years' experience, desires to change. No. 32.

Member, technical graduate, aged 30, with eight years' experience in copper smelting, is open for engagement. At present acting superintendent of a large copper smelter. No. 33.

### AFFILIATED STUDENT SOCIETIES.

Any society of undergraduates at a technical school, comprising students in any branch of engineering, metallurgy, chemistry, geology, etc., may be recognized by the Board of Directors in its discretion as an Affiliated Student Society. A circular giving details of the plan of affiliation may be obtained on application to the office of the Secretary of the Institute.

The following societies have been placed by authority of the Board of Directors on the above list:

#### AFFILIATED STUDENT SOCIETIES.

The Mining Society of the Sheffield Scientific School, Yale University, New Haven, Conn. *President*, Francis S. Winslow; *Secretary*, Roger W. Newberry.

The University of Illinois Student Branch of the American Institute of Mining Engineers, Urbana, Ill. *President*, M. L. Nebel; *Secretary*, Willis Leriche.

The Engineering Society of the University of Nevada, Reno, Nev. *President*, P. E. Raymond; *Secretary*, R. M. Seaton.

The University of Wisconsin Mining Club, Madison, Wis. *President*, Rudolph J. Stengl; *Secretary*, Mack C. Lake.

The Mining and Geological Society of Lehigh University, South Bethlehem, Pa. *President*, Robert C. Mickel; *Secretary*, Edward B. Snyder.

The School of Mines Society of the University of Minnesota, Minneapolis, Minn. *President*, C. A. Walker; *Secretary*, A. C. Bierman.

The Mining Engineering Society of the Massachusetts Institute of Technology. *President*, Ralph E. Wells, Jr.; *Secretary*, Louis W. Currier.

The Student Auxiliary Society of the American Institute of Mining Engineers of the University of Kansas, Lawrence, Kan. *President*, Walter E. Rohrer; *Secretary*, H. R. Brown.

The Associated Miners of the University of Idaho, Moscow, Idaho. *President*, Walter P. Scott; *Secretary*, Bert F. Smith.

The State College of Washington Mining and Geological Society, Pullman, Wash. *President*, John F. Foran; *Secretary*, Thomas C. Puckett.

The Tejas Technical Society, School of Mines, University of Texas, Austin, Tex. *President*, G. C. Cartwright; *Secretary*, David S. Alley.

The Ohio State University Student Branch of the American Institute of Mining Engineers, Columbus, Ohio. *President*, Hugh B. Lee; *Secretary*, E. P. Elliott.

The Stanford Geology and Mining Society, Stanford University, Cal. *President*, B. E. Parsons; *Secretary*, E. D. Nolan.

The Senior Mining Society of Columbia University, New York, N. Y. *President*, Roger L. Strobel; *Secretary*, Clark G. Mitchell.

Mining Association of the University of California, Berkeley, Cal. *President*, D. M. Drumbeller, Jr.; *Secretary*, J. B. Orynaki.

Tufts College Chemical Society, Tufts College, Mass. *President*, F. D. Whittemore; *Secretary*, E. W. Hays.

University of Washington Mining Society, Seattle, Wash. *President*, Oliver P. Searing; *Secretary*, Albert R. Sherman.

Student Branch of the American Institute of Mining Engineers, Iowa State College, Ames, Iowa. *President*, Lyle A. Butler; *Secretary*, A. J. Crawford.

Missouri Mining Association of the Missouri School of Mines, Rolla, Mo. *President*, L. S. Copelin; *Secretary*, L. J. Boucher.

The Pick and Shovel Club of the Case School of Applied Science, Cleveland, Ohio. *President*, M. T. Whelan; *Secretary*, Lloyd A. Collier.

Colorado School of Mines Scientific Society, Golden, Colo. *President*, Alan Kiscock; *Secretary*, George Wilfley.

Mining Engineering Society of the University of Arizona, Tucson, Ariz. *President*, J. Gary Lindley; *Secretary*, H. O. Coles.

Kentucky Mining Society, College of Mines and Metallurgy, University of Kentucky, Lexington, Ky. *President*, Oliver W. Smith; *Secretary*, Charles E. Straub.

Mining Society of Pennsylvania State College, State College, Pa. *President*, Ralph E. Kirk; *Secretary*, Willard M. Lindsey.

**S. F. EMMONS RESEARCH FELLOWSHIP.**

movement was started by a number of the friends and admirers of S. F. Emmons, Economic Geologist of the United States Geological Survey, to perpetuate his name through a fellowship to be known as the Emmons Research Fellowship," and they have succeeded in raising \$13,000 for the purpose of carrying on research work in economic geology.

The Committee in charge of this Memorial Fund has succeeded in obtaining the co-operation of Professors Kemp, of Columbia, Irving, of Yale, and Duggen, of Massachusetts Institute of Technology, in the administration of this fellowship. These three gentlemen are respectively geologists of the institutions mentioned and are exceptionally qualified to advise in what direction the fund can be best administered. It is expected that additional contributions will be forthcoming from many who have heard of this movement. Subscriptions are invited and may be sent to any of these gentlemen, or to Benjamin B. Lawrence, Treasurer, 100 Wall Street, New York City.

**BACK VOLUMES OF THE TRANSACTIONS.**

The Board of Directors has authorized the following offers of sets of back volumes of the *Transactions*, at considerably reduced prices, to Members, Societies, and Scientific Societies:

|                                                                                                                                                                                | Per Set. |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| Back volumes, bound in half-morocco, from No. 36 (1906) to No. 40 (1910),                                                                                                      | \$20     |
| Back volumes, bound in half-morocco, from No. 31 (1902) to No. 40 (1910), including Mexican Volume,                                                                            | 35       |
| Back volumes, bound in half-morocco, from No. 21 (1893) to No. 40 (1910),                                                                                                      | 50       |
| Back volumes, bound in half-morocco, from No. 11 (1883) to No. 40 (1910),                                                                                                      | 60       |
| Back volumes, bound in half-morocco, from No. 1 (1873) to No. 40 (1910), with the exception of No. 10 (1882), but including index for Volumes Nos. 1 to 35, and Nos. 36 to 40, | 75       |
| Back volumes, bound in half-morocco, from No. 1 (1873) to No. 9 (1881),                                                                                                        | 25       |

**INTERNATIONAL ENGINEERING CONGRESS.**

The International Engineering Congress of 1915 will be held under the auspices of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society of Professional Architects and Marine Engineers, and the American Institute of Mining Engineers, in connection with the Panama-Pacific Exposition. Arrangements for this Congress are now proceeding under the General Committee, the Institute representatives on which are given on p. xxix. An interesting technical program is promised. The time of the Congress will be from October 20 to 25, 1915. Members of the Institute are cordially invited to attend and participate in the proceedings of the Congress.

## IRON AND STEEL COMMITTEE.

ALBERT SAUVEUR, *Chairman.*A. A. STEVENSON, *Vice-Chairman.*HERBERT M. BOYLSTON, *Secretary, Abbot Bldg., Cambridge, Mass.*

John Birkinbine,  
William H. Blauvelt,  
James Gayley,  
Henry D. Hibbard,  
Henry M. Howe,  
Robert W. Hunt,  
J. E. Johnson, Jr.,

William Kelly,  
Charles Kirchhoff,  
Richard Moldenke,  
Joseph W. Richards,  
C. F. W. Rys,  
E. Gybbon Spilsbury,

J. S. Unger,  
Felix A. Vogel,  
Leonard Waldo,  
William R. Walker,  
William R. Webster,  
Frederick W. Wood.

The innovation of a special meeting under the auspices of the Iron and Steel Committee was well justified, if we accept as a criterion the number of papers presented at the meeting held on Oct. 16 and 17 in New York and the attendance at that meeting. Twenty-four papers were read, and most of these were widely discussed orally, while doubtless the written discussions will be even larger in extent. Discussions will be received up to Dec. 1, 1913. The attendance at the meeting of 106 members and 75 guests is an evidence of the wide and growing interest in the Institute of men interested chiefly in iron and steel. It is especially interesting to note this large attendance at a meeting where very little of a social nature was introduced into the program.

An informal dinner for the men at the Engineers' Club closed the meeting. At this dinner were present about 70 members and guests. One of the Vice-Chairmen and the Secretary of the new Committee on Petroleum and Gas told of the important plans in prospect of that Committee. Brief impromptu speeches by a considerable number of the members and guests were enjoyed. Professor Marburg reiterated his previous assertion that he believed that the Institute and the American Society for Testing Materials, as well as some of the other technical societies, were all fighting for one good cause; that there was room in the field for all of these societies with their various points of view; and that they should march shoulder to shoulder. The success of this dinner was due largely to the efforts of Mr. Johnson, who had the affair in charge.

The fact that all of the papers that were presented, with two exceptions, were distributed in printed form speaks well for the efficiency of the General Secretary's office, handicapped as it was by the fact that about half of the manuscripts were received after Sept. 1.

In view of the excessive pressure of work put upon the Committee and upon the General Secretary's office, because of the late date at which some of the manuscripts have been received in the past, it has been decided that no papers received after Jan. 1, 1914, can be presented at the next February meeting and, in general, it will be much better if the papers can be in the hands of the Secretary at least three months in advance.

Papers on the following subjects are practically assured for the February meeting:

Albert Sauveur, Mayari Steel.

J. E. Johnson, Jr., The Quality of Cast Iron as Affected by Oxygen, Nitrogen, and Other Elements.

J. L. Norris, Resistance of Steels to Wear in Relation to Their Hardness and Tensile Properties.

J. V. Emmons, Some Phases of the Practical Treatment of Tool Steel.

G. H. Clamer, Cupro-Nickel Steel.

interesting meeting of the Iron and Steel Committee was held at Engineers' Club, in New York, on the evening of Oct. 16. Several were present and possible topics for future papers were discussed. as a result of this meeting, invitations have been sent out to persons to contribute papers on the following subjects for the next meeting: The Electric Furnace for Steel Making; The Electric Furnace for the Manufacture of Steel Castings; The Generation of Steam from Heat from Open-Hearth Furnaces; Special Steels; Heat Treatment of Steel Castings; Mayari Steel Rails; Nodulizing of Ores for the Blast-Furnace; Blast-Furnace Gas Cleaning; The Efficiency of Blast-Furnace Stoves.

H. M. BOYLSTON, *Secretary*.

## COMMITTEE ON PETROLEUM AND GAS.

ANTHONY F. LUCAS, *Chairman*.

WILLIAM N. BEST, *Vice-Chairman*,

DAVID T. DAY, *Vice-Chairman*,

MARK L. REQUA, *Vice-Chairman*.

LEONARD WALDO, *Secretary*, 49 Wall St., New York, N. Y.

Philip Arnold,  
Derrick G. Clapp,  
Vin T. Dumble,  
Edward S. Haseltine,  
Willard Hayes,

Philip W. Henry,  
John Langton,  
William B. Phillips,  
Walter O. Snelling,

William L. Watts,  
H. A. Wheeler,  
I. C. White,  
William A. Williams.

The first regular meeting of the Committee was held at the Engineers' Club on Wednesday evening, Oct. 15, 1913. The Committee asked for an allotment of time at the February meeting of the Institute at which to hold a symposium on the subject of the origin of petroleum and natural gas. Day submitted a chart giving a classified list of subjects that would come within the scope of the Committee's activities, together with the names of men best fitted to treat the various subjects.

Waldo, Chairman of the Sub-Committee on Fire Protection and Insurance, reported that in connection with the work of this Committee the Institute had become a member of the National Fire Protection Association. William N. Best offered a list of four subjects as being worthy of receiving the attention of the Committee, and was urged to prepare a paper on each of the points.

Waldo presented the following resolution, which was adopted and referred to the Editor of the *Bulletin* for publication in the next issue:

The Petroleum and Gas Committee of the American Institute of Mining Engineers hears with sorrow of the death of Dr. Rudolph Diesel. He was the first amongst those engineers of acute perception, high technical training and scientific imagination who have applied the revealing principle of the conservation of chemical and heat transforming energy to the service of man. The energy economies he has pointed out to us are of incalculable value. His services, as his training, were international in character. It is pathetic that just as he was entering into the fruition of his noblest plans, which had been so unflinchingly pursued through many struggling years, he should leave the goodly fellowship of his sympathizing colleagues, who can only with far less fitness carry on the great branch of Mechanical Engineering so convincingly established by him."

LEONARD WALDO, *Secretary*.

## BOSTON LOCAL SECTION.

*Committee.*ROBERT H. RICHARDS, *Chairman.*ALBERT SAUVEUR, *Vice-Chairman.*AUGUSTUS H. EUSTIS, *Secretary-Treasurer*, 131 State St., Boston, Mass.

TIMOTHY W. SPRAGUE.

HENRY A. WENTWORTH.

The thirteenth meeting of the Boston Local Section was held at the Engineers' Club, 2 Commonwealth Avenue, Boston, on Monday evening, Oct. 6, 1913. Fourteen members and three guests were present at the dinner, at which Chairman Robert H. Richards presided.

After the dinner, the Chairman expressed his pleasure in welcoming the members at the first dinner following the vacation. He said that he had attended a meeting of the Directors of the parent society in New York; that they had asked what the Boston Section were doing, and expressed their hope that we would be able to make some of our papers formal and offer them for publication. The Chairman then said that he realized the objection to this; that members were less willing to speak for publication than informally, but that he hoped, nevertheless, that some of the speakers this year would see their way to write up a formal paper at some later date, along the general lines of their informal addresses.

At the close of the Chairman's remarks, the minutes of the twelfth meeting were read in part, and approved.

The Secretary reported that he had received a letter from Mr. Jennings, suggesting that Mr. Bruno Nordberg had recently been testing a new form of hoisting engine, which combined an air compressor and steam hoist, and that he might possibly consent to present the results of these tests in a paper to the Boston Section. The Secretary asked if the members would be interested in such a paper, and the reply was, that they would.

The Chairman then introduced the speaker of the evening, Prof. Henry L. Smyth, who spoke informally on The Taxation of Mining Property.

At the close of the paper, Mr. Weeks entertained the company by reciting a few verses.

The meeting then adjourned.

AUGUSTUS H. EUSTIS, *Secretary.*

## LIBRARY.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

AMERICAN INSTITUTE OF MINING ENGINEERS.

UNITED ENGINEERING SOCIETY.

WILLIAM P. CUTTER, Librarian.

Library of the above-named Societies is open from 9 A.M. to 9 P.M. week-days, except holidays, from September 1 to June 30, and from 10 to 6 P.M. during July and August. The Library contains about 10,000 volumes, including sets of technical periodicals and the publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To the Library can render valuable service through correspondence; requests for information will receive special attention. The Library is prepared to furnish references and copies of articles on mining and metallurgical subjects; to determine the existence of mining-maps, and to furnish general information as to the geology and mineral resources of all countries.

Communications should be made as definite as possible so that the information received may be what is desired and not include collateral information which may not be of interest. The time spent in searching for such material will be saved, and the information will be sent more promptly and in more usable shape.

Members of the Institute can be of service to the Library by forwarding copies of mining-reports, maps privately issued, and similar material, which will be classified, indexed, and made available to other members. Suggestions for additions to the Library, either by purchase or personal solicitation as gifts, will be welcomed. It is hoped that members in the city will use the Library freely, and assurance is given that the most careful service will be rendered to them.

## LIBRARY ACCESSIONS.

## New Books on Mining and Metallurgy.

ANALYTICAL SUMMARY OF THE MINING AND METALLURGICAL INDUSTRIES OF CANADA, 1907-08. Canadian Mines Department, Ottawa, 1908. (Gift of International Geological Congress (Canada), 1913.)

MINES—SOUTH AFRICA (UNION) MINES DEPARTMENT. Annual Report, 1912, Part III. Pretoria, 1913. (Gift of Union of South Africa Mines Dept.)

FOR MINE-RESCUE AND FIRST-AID FIELD CONTESTS. (Miners' Circular No. 15, U. S. Bureau of Mines.) Washington, 1913. (Exchange.)

MINING AT MINING VILLAGES IN THE BIRMINGHAM DISTRICT, ALA. (Technical Paper No. 33, U. S. Bureau of Mines.) Washington, 1913. (Exchange.)

AND CADMIUM. By R. G. Max Liebig. Leipzig, 1913. (Purchase.)

## New Books on Geology and Mineral Production.

ANALYTICAL SUMMARY OF THE MINERAL PRODUCTION OF CANADA, 1912. Canadian Department of Mines, Ottawa, 1913. (Gift of Department of Mines.)

MINERAL MAP OF THE DOMINION OF CANADA, 1913. (Gift of International Geological Congress (Canada), 1913.)

MINERIA MINERA DE CHILE EN 1910. Encomendada a la Sociedad Nacional de Minería. Tomo V. Santiago de Chile, 1913. (Exchange.)

JAHRBUCH FÜR MINERALOGIE, GEOLOGIE UND PALÄONTOLOGIE. Beilage-Band. LXVI, part 2. Stuttgart, 1913. (Purchase.)

PRELIMINARY REPORT ON IRON ORES OF MISSISSIPPI. (Bulletin No. 10, Mississippi Geological Survey.) Jackson, 1913. (Exchange.)

TITANIFEROUS IRON ORES IN THE UNITED STATES; THEIR COMPOSITION AND ECONOMIC VALUE. (Bulletin No. 64, U. S. Bureau of Mines.) Washington, 1913. (Exchange.)

VICTORIA. SECRETARY FOR MINES. Annual Report, 1912. Melbourne, 1912. (Exchange.)

### New Books on Non-Metallic Minerals.

U. S. NAVY DEPARTMENT. Report of the U. S. Naval "Liquid Fuel" Board. Washington, 1904. (Gift of U. S. Navy Department.)

INVESTIGATION OF THE COALS OF CANADA, VOL. 1-6. Canadian Mines Department, Ottawa, 1912. (Gift of International Geological Congress (Canada), 1913.)

STRUCTURAL MATERIALS OF MISSISSIPPI. (Bulletin No. 9, Mississippi Geological Survey.) Jackson, 1911. (Exchange.)

ANALYSES OF COALS IN THE UNITED STATES. (Bulletin No. 22, U. S. Bureau of Mines, parts 1-2.) Washington, 1913. (Exchange.)

### New Books on Chemistry and Physics.

TABLES ANNUELLES DE CONSTANTES ET DONNÉES NUMÉRIQUES DE CHIMIE, DE PHYSIQUE ET DE TECHNOLOGIE. Volume II, Année 1911. Paris, 1913. (Gift of VIIth International Congress of Applied Chemistry.)

[NOTE.—Those who have used the first volume of this great work will welcome the second, and will need no aid to the grateful appreciation of it. The International Association of Academies, under the auspices of which these tables have been compiled and published, could not have bestowed upon the scientific world a greater boon. While the text is largely French, all necessary explanations are given in German, Italian, and English also. The tables in this volume comprise the following subjects: Coefficients of Compressibility, Elasticity, Densities, Viscosity; Surface-Tension; Coefficients of Expansion; Specific Heats; Thermal Conductivities; Thermodynamics; Melting Points; Vapor Pressures; Gas Laws; Acoustics; Radiation; Photometry Coefficients of Absorption; Refraction and Dispersion; Spectrum Analysis; Optical Rotatory Powers; Electricity; Magnetism; Atomic Properties; Radio-activity; Cosmic Physics; Atomic Weights; Molecular Weights; Osmotic Pressure; Coefficients of Diffusion; Solubility; Thermochemistry; Chemical Equilibrium; Velocity of Reaction; Electrical Conductivity of Electrolytes; Electromotive Forces; Colloids; Absorption; Crystallography and Mineralogy; Organic Chemistry; Essential Oils, Fats and Waxes; Animal Physiology; Vegetable Physiology and Chemistry; Engineering; Metallurgy—and a supplement. There are 759 quarto pages in all, representing, one might fairly say, the latest discoveries and determinations in the whole realm of science.—R. W. R.]

### New Books on General Subjects.

CANADA. COMMISSION OF CONSERVATION. Report of the 4th Annual Meeting, Jan., 1913. Toronto, 1913. (Gift of Commission of Conservation.)

OM HASTSKOSÖMMETODEN OCH TILLVERKNINGEN SAMT NÅGRA DRAG UR HOFBESLAGETS HISTORIA. By K. J. Sunström. Örebro, 1911. (Gift of F. B. Gilbreth.)

The author desires very much to have samples of every kind of horseshoe nail that there is, in order that his next book on this subject may include American as well as European. K. J. Sunström, Örebro, Sweden.

OPISANIE SOORUSHENIG NOVAGO MOSKOVSKAGO VODOPROVODA (Water Works System of Moscow, Russia), with atlas (in Russian). By N. P. Simin. Moskba, 1905. (Gift of Walter Wood.)

PANAMA CANAL. WHAT IT IS, WHAT IT MEANS. By John Barrett. Washington, 1913. (Gift of Pan American Union.)

RAILWAY LIBRARY, 1912. Compiled and edited by Slason Thompson. Chicago, 1913. (Gift of Slason Thompson.)

TARIFF LAW OF 1913. New York, 1913. (Gift of W. P. Cutter.)

VOCABULARIO GUARANI. Ráimundo D. Obelar. N. p., n. d. (Gift of George B. Holderer.)

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION. Proceedings of 20th Annual Meeting. Vol. XX, part 2. Ithaca, 1913. (Gift of Society for the Promotion of Engineering Education.)



—The first danger of a Society like this is that, offering a forum for the presentation of new ideas, it may be swamped in the voluminous deliverances of diluted by the platitudes of conservatives. The record of this Society shows that danger need not be apprehended. It has become the organ of keen practical experimenters and mere theorists or figure-heads. This volume, containing the proceedings of a meeting of June, 1912, contains several papers of special and permanent value, and engineering laboratories of all kinds. Among these one of the most suggestive is that of Prof. W. T. Magruder, of the Ohio State University, on The Characteristics of Mechanical Engineering Laboratories of American Engineering Colleges, in which he discusses the specialties emphasized, the equipment and its use, the personnel employed, the time devoted to laboratory work, the system of individual or squad work, the methods of experiments and record, the amount of original research, etc., are discussed. The author says he learned something at every laboratory he visited.

Prof. R. Heuter furnishes an elaborate description of the famous laboratories at Freiberg; and the Section on Mining Laboratories presents an interesting discussion of the educational purposes of a laboratory and the essential equipment of laboratories for ore dressing, coal washing, ore testing, metallurgy, and mining. The volume is sold to non-members at \$1.25 per copy, which is below the cost of production, and may be obtained from Henry H. Norris, Secretary, Ithaca, N. Y.—R. W. R.]

### Company Reports.

(GIFT OF INTERNATIONAL GEOLOGICAL CONGRESS (CANADA), 1913.)

COLUMBIA COPPER CO. Annual Report, 1912.

Description of Smelting Works at Greenwood, British Columbia. By J. E. McEwen.

DEER CREEK MINES, LTD. Annual Report, 7th, 1913.

INTERNATIONAL MINING & SMELTING CO. OF CANADA. Report of the Directors, 1912.

MINES CO., LTD. Annual Report, 2d, Nov., 1911–March 31, 1913.

PORTLAND CEMENT CO. OF CANADA, LTD. Annual Report and Statement, March 31, 1913.

brief account of its coal and steel properties.

CONSOLIDATED MINING, SMELTING & POWER CO., LTD. Report, 1912.

GOLD MINING CO. Report, 1912.

NEW GOLD MINES, LTD. Annual Report, 2d, 1912.

BAY MINES, LTD. Annual Report, 3d, 1912.

NATIONAL NICKEL CO. Annual Report, 11th, 1913.

LAKE MINING CO. Annual Report, 1912.

KEY-DARRAH-SAVAGE MINES OF COBALT, LTD. Report, 1912.

GOLD MINES CO. Annual Report, 8th, 1912.

SUPERIOR SILVER MINES, LTD. Annual Report, 1st, 1913.

COMPANY OF CANADA, LTD. Report, 3d, 1912.

GOLD CO. Annual Statement to the Stockholders, 1912.

SUFFER LOBBAIN SILVER MINES, LTD. Annual Report, 1912.

### Trade Catalogues.

PNEUMATIC TOOL CO., Chicago, Ill. Bull. No. 34-T. Class "M" Chicago Pneumatic Corliss Type Steam-Driven Compressors. Sept., 1913.

ALL-RAND CO., New York, N. Y.

new remarks about Calyx Coredrills. (Form 632.)

"Little David" riveting hammers. (Form 8011.) July, 1913.

W. A. & SONS ROPE CO., St. Louis, Mo. Leschen's Hercules. Oct., 1913.

ROEBLING'S SONS CO., Trenton, N. J. Catalogue of wire rope and wire rope fittings. 1912.

NEW MACHINERY CO., Chicago, Ill. Catalogue 68. Sullivan Stone Channelers.

VERGNE MACHINE CO., New York, N. Y. Bull. 132. "De La Vergne" Oil Engine, type "F H." June, 1913.

WEBSTER MFG. CO., Tiffin, Ohio. Webster Method. Sept., 1913.

## MEMBERSHIP.

## NEW MEMBERS.

The following list comprises the names of those persons who became members during the month of October, 1913:

*Members.*

|                                                                                      |                                                    |
|--------------------------------------------------------------------------------------|----------------------------------------------------|
| BARNES, KENNETT F., Secty.....                                                       | Granby Min. & Smelting Co., St. Louis, Mo.         |
| BILLINGSLEY, PAUL, Geol.....                                                         | 526 Hennessy Bldg., Butte, Mont.                   |
| BLANCHORD, RALPH C., Geol.....                                                       | 3 Lombard St., London, England.                    |
| BOYLE, ALBERT C., Jr., Prof. of Min. and Met., University of Wyoming, Laramie, Wyo.  |                                                    |
| BRADFORD, JULIUS S., Min. Engr.....                                                  | Chiksan Mining Co., Chiksan, Korea.                |
| CLEMES, ALFRED W., Min. Engr.....                                                    | P. O. Box 688, Morenci, Ariz.                      |
| COPELAND, DURWARD, Met.....                                                          | Cia. Estamifera de Llalagua, Bolivia, So. America. |
| CRAWFORD, JOHN, JR., Mgr.....                                                        | Noble Elec. Steel Co., Heroult, Shasta Co., Cal.   |
| EDWARDS JOHN R., Naval Officer.....                                                  | Navy Dept., Washington, D. C.                      |
| FARNHAM, C. MASON, Geol., Cerro de Pasco Mining Co., Cerro de Pasco, Peru, So. Amer. |                                                    |
| FOWLER, GEO. M., Min. Engr.....                                                      | 634 Phoenix Bldg., Butte, Mont.                    |
| GILHAM, RALPH E., Asst. Supt.....                                                    | Keating Gold Dredging Co., Radersburg, Mont.       |
| KENNEDY, ANDREW, Min. Engr.....                                                      | 1215 3d Ave., N., Seattle, Wash.                   |
| PORTER, W. E., Mining.....                                                           | 427 Gas and Electric Bldg., Denver, Colo.          |
| RATHBUN, FRANK DE G., Min. Engr.....                                                 | Morenci, Ariz.                                     |
| RYE, C. F. W., Met. Engs.....                                                        | Carnegie Steel Co., Carnegie Bldg., Pittsburg, Pa. |
| SIMENSTAD, CHARLES, Min. Engr.....                                                   | 2305 13th Ave., North, Seattle, Wash.              |
| SOPER, ELLIS C., Mech. Engr.....                                                     | Pres. Soper Engrg. Co., Chattanooga, Tenn.         |
| SUNDERHAUF, ALBERT E., Mining.....                                                   | Baramaribo, Dutch Guiana, So. America.             |
| SUVERKROP, EDWARD A., Chile Exploration Co., 251 W. 109th Street, New York, N. Y.    |                                                    |
| WARE, HARRY S., Met.....                                                             | Box 3, Anaconda, Mont.                             |
| WEAVER, CHARLES E., Geol.....                                                        | University of Washington, Seattle, Wash.           |
| WESTER, JAMES R., Mine Foreman.....                                                  | Morenci, Ariz.                                     |
| WILCOX, RALPH, Diamond Drill Operator.....                                           | P. O. Box 100, Miami, Ariz.                        |

*Associate.*

|                                     |                 |
|-------------------------------------|-----------------|
| BRADLEY, CLARENCE I., Student ..... | Branford, Conn. |
|-------------------------------------|-----------------|

*Junior Members.*

|                                                                                      |                                          |
|--------------------------------------------------------------------------------------|------------------------------------------|
| CRITTENDEN, ZAR T., Min. Engr.....                                                   | Lincoln Block, Butte, Mont.              |
| DOBSON, CHRISTOPHER G., Asst. Engr., Original Mine, 303 Goldberg Bldg., Butte, Mont. |                                          |
| MADSON, FRANK H., Min. Engr.....                                                     | 517 S. Central Ave., Virginia, Minn.     |
| PETTY, MORRIS K., Transimtan.....                                                    | Ellsworth Collieries Co., Ellsworth, Pa. |
| SEARING, OLIVER P., Cyaniding.....                                                   | Treadwell, Alaska.                       |
| STILLWAGON, SAMUEL C., Efficiency Work.....                                          | 2056 Cornell Pl., Cleveland, Ohio.       |
| WONG, WILLIAM A., Student, Livingston Hall, Columbia University, New York, N. Y.     |                                          |

## CANDIDATES FOR MEMBERSHIP.

The following persons have been proposed during the month of October, 1913, for election as members of the Institute. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

*Members.*

Alexander Adiassewich, St. Petersburg, Russia.  
 Proposed by W. L. Saunders, L. Waldo, Albert Sauvour.  
 Born, 1865, Kamenetz-Podolsk, Russia. 1874-84, College at Kamenetz-Podolsk, University at Kharkow; Natural Science. 1897-1900, studying Geology and Mining in London. 1884-87, Exploration work in Altai Mountains, Siberia. 1887-92, Engineer at oilfields and refineries in Baku, Caucasus. 1892-95, Exploration work for Gouzia Mines Synd.

ing engineer, Sismadan Copper Mines. 1895-97, Manager and consulting engineer  
us companies operating in Baku oilfields. 1897-1908, Consulting Mining engi-  
London.

st position: 1908 to date, Member of Ministry of Commerce and Industry, Russia.  
geological bureau and laboratory for English petroleum companies working at

W. Beard, Rincon, Temascaltepec, Mexico.

ed by C. E. Rhodes, A. F. Main, Blamey Stevens.

1883, Syracuse, N. Y. 1904-08, C. E. Syracuse University. 1908-09, B. S. in  
Missouri School of Mines. 1909-10, Mine Foreman, Gold Pioneer Mining Co.,  
e, Colo. 1910-11, Mining Engineer, Oaks Co., Alma, N. M. 1911-12, Shift boss  
and Mill, El Oro Mining and Railway Co., El Oro, Mexico.

st position: 1912 to date, Mine Supt., Lane-Rincon Mines, Inc., Temascaltepec,

Bertram Arnold, New York, N. Y.

ed by W. H. Barrows, Jr., Carl Zapffe, Kirby Thomas.

1866, Stanley, N. B. 1881, High School, Meonee, Wis. 1882-84, University of  
1884-1913, Law office and practicing attorney in Wis. and Minn. Part owner in  
holding companies of iron lands in Minnesota from 1891 to date. I have been  
d in copper and iron land and mines in Wisconsin and Minnesota, always for my-  
owner.

st position: Holding and developing iron lands.

Asano, Tokyo, Japan.

ed by R. Konda, M. Otegawa, I. Sugimoto.

1876, Tokyo, Japan. 1900, Grad., Applied Chemistry Section, Technology Depart-  
Tokyo Imperial University. Oct. to May, 1901, Mass. Inst. Technology. 1902,  
pper Mine's Smelter of Furukawa Mining Co. as engineer. 1906, Superintendent  
ume. 1913, Engineer of Main Office of the same company. Traveled United  
see the progress of mining industry.

st position: Engineer of Furukawa Mining Company.

r O. Borchardt, Austinville, Va.

ed by J. A. Van Mater, William A. Pomeroy, George C. Stone.

1883, Chicago, Ill. 1890-1901, Chicago Public Schools, Chicago English High  
ual Training School. 1901-05, Stevens Institute of Technology, Hoboken, N. J.;  
f Mechanical Engineer. 1901, summer, Warren Manufacturing Company, Chi-  
odworking and cabinet making. 1903, summer, Illinois Steel Co., Chicago, Con-  
Department. 1904, summer, Cudahy Packing Co., S. Omaha, Neb., Engineering  
1905, summer, Electric Vehicle Co., Washington, D. C., Machine Shop. 1905, 3  
N. Y. & Queens Gas Co., Flushing, L. I., Inspector on contracts. Dec., 1906,-  
06, Milliken Bros., Inc., New York City, Detailer on design of Open Hearth  
nt. Mar., 1906, New Jersey Zinc Co., Franklin Furnace, N. J. Ore Conc. and  
ngrg. Sept., 1906, to date, Bertha Mineral Co., Austinville, Va.; Asst. Supt. and  
ine, Mill, Smelter.

st position: Superintendent Austinville Plant, Bertha Mineral Co.

E. Chase, Jr., Tacoma, Wash.

ed by Willard V. Morse, P. A. Mosman, Willard S. Morse.

1887, St. Paul, Minn. 1901-5, Tacoma High School. 1905-9, University o  
Bachelor of Science in Chemistry. 1909-11, Successively furnaceman, MacDou-  
eman, sample foreman, chemist, and yard foreman at smelter of Cerro de Pasco  
Co., Peru. Feb-Sept., 1912, Chemist with Heinrich Laboratories, Tacoma.

st position: Oct., 1912, to date, Tacoma Smelting Co.

m Morley Cobeldick, Wallaroo, South Australia.

ed by H. Lipson Hancock, William E. Slee, Albert L. Brown.

1882, London, England. 1896-98, Finsbury Technical College, London, England.  
1, British Columbia Exploring Syndicate subsequently Electrical Engineer Co.'s  
ing plant on the Fraser River; had charge of erection and operation of power  
d the melting and assaying of gold. Obtained Diploma of British Govt. for effi-  
sampling and assaying. 1901-05, Works Manager and Chemist to the Metal  
d., London, England, dealing with the technical and commercial development of  
bourne Ashcroft's chlorine treatment of lead-zinc sulphides. 1905-07, Took asso-  
course at Royal School of Mines, London; awarded Bessemer Medal and prize in  
llurgical Department. Six months inspecting metallurgical plants, Gt. Britain

and Europe. 1907-09, Treating tin-copper sulphides from the Oonah Mines, Ltd., Tasmania and London, which included erecting and operating experimental reverberatory plant, together with leaching treatment of this ore at Swansea, South Wales, in conjunction with Messrs. A. Hill and Stewart, London. 1910, Special study treatment of Cu-Sn mattes and alloys.

Present position: 1910 to date, Chemist, Wallaroo & Moonta Mining & Smelting Co. Ltd., Wallaroo, South Australia.

**John Victor Culbert**, London, Ontario, Canada.

Proposed by R. E. Hore, Thomas T. Read, R. H. Flaherty.

Born, 1887, Granton, Ont. 1904-07, University of Toronto, Ont., grad. in mining engineering. 1908-09, Post-graduate, University of Toronto; degree of Bachelor of Applied Science. 1911, Member Canadian Institute of Mining Engineers. 1905-08, Timbering, surveying, assaying, prospecting, mill shifting, O'Brien Mine, Cobalt, Ont. 1909-10, Shiftboss, Esperanza mine, El Oro, Mexico; Smelter Supt., Dos Estrellas mine, El Oro, Mexico; Surveyor and experimental man on construction of cyanide mill, El Tigre Mine, Sonora, Mexico. 1911, Engineer for Willis Chipman, C. E., Toronto: Sampler, Assayer, Mill Supt., Hollinger Mine, Porcupine, Ont. 1912, Estimating and drafting, Toronto Iron Works. 1913, Mining Engineer and Surveyor, Buffalo Mines, Cobalt.

Present position: Mine Superintendent, Wasabika Gold Mine, West Shiningtree, Ont.

**Mitchell Joseph Daley**, Bingham Canyon, Utah.

Proposed by Vernon S. Rood, E. P. Jennings, H. D. Kinney.

Born, 1885, Marlboro, Mass. Grammar and High School. 1909, Grad. of Mass. Institute of Technology; degree S. B. 1909-10, General work in Mill, Sampler and engineer's asst. 1911, Assayer. 1911-13, Mill Supt. with Utah Apex Mining Co.

Present position: Mill Supt., Utah Apex Mining Company.

**Freeman Monroe Dodson**, Bethlehem, Pa.

Proposed by Joseph W. Richards, Henry S. Drinker, Benjamin L. Miller.

Born, 1877, Bethlehem, Pa. 1896-1900, Lehigh University, Bethlehem, Pa. Degree B. S. 1899, Asst. Chemist, Nazareth Portland Cement Co., Nazareth, Pa. 1902, Supt., Monroe Coal Mining Co., Barnum, W. Va. 1903, Supt., Osceola Coal & Coke Co., Weston Coal & Coke Co., Osceola Mill, Pa. 1906, to date, Vice-President and Manager of Dodson Coal Co., Charles M. Dodson & Co., Locust Mt. Coal Co., anthracite mines in the Hazleton-Pottsville region.

Present position: As above.

**William Spencer Elphinstone**, Bengal, India.

Proposed by C. P. Perin, C. W. Weld, A. F. Bennett.

Born, 1879, Shipley, England. 1890-97, Nottingham. 1900-01, Derby and Sheffield University. 1897-1905, Deputy and Undermanager at West Hailham Colliery. 1905-07, Manager, Winfield Manor Colliery. 1907-09, Manager, Ashgate Colliery. 1909-11, Manager, Bhelaland Colliery.

Present position: 1912 to date, Chief Mining Engineer, Tata Iron & Steel Co., Ltd., Bengal, India.

**Bancroft Gore**, Butte, Montana.

Proposed by E. P. Mathewson, Frederick Laist, N. H. Emmons.

Born, 1879, Auburndale, Mass. 1900, Harvard College, degree A. B. 1900-02, Assayer, Feather River Mining Co., Butte County, Cal. 1902-05, Chemist and Supt. of Cyanide Plant, Zacatecas La Central Mining Co., Zacatecas, Mexico. 1905-08, Exploration work in Mexico. 1906-08, Chemist, new reduction works Anaconda Copper Mining Co., Anaconda, Mont. 1908-13, Smelter Supt., Compania de Minas de Cobre de Gatico, Gatico, Chile.

Present position: Professor of Metallurgy and Ore Dressing, Montana State School of Mines, Butte, Montana.

**Vicor Carl Grubman**, Palmerton, Pa.

Proposed by H. O. Hofman, Carl R. Harvard, Edward E. Bugbee.

Born, 1887, Philadelphia, Pa. 1899-1904, Cheltenham Military Academy, Ogontz, Pa. 1904-09, Massachusetts Institute of Technology, Boston; Bachelor of Science, Mining Engineering and Metallurgy. 1909-12, Assayer, Chemist, and Chief Chemist American Smelters Securities Company, Vetardona Smelter, Amaro, Durango, Mexico. 1912 to date, Employed by New Jersey Zinc Company of Pa., at their smelter located at Palmerton, Pa.; Chemist until Feb. 1913, Zinc Oxide Department.

Present position: No title but in the capacity of Assistant Chief of Zinc Oxide Department (West).

George Hall, Kansas City, Mo.  
 ed by Bradley Stoughton, H. F. Wierum, P. A. Mossman.  
 1872, Ireland. 1897, Mass. Institute of Technology, Boston, (97) B. S. in Chem-  
 Metallurgy. 1897-1901, Chemist, Pueblo S. & R. Company and American S. &  
 any, Pueblo, Colo. 1901-03, Mining. 1903-13, Chemist, Asst. Supt., Supt.,  
 nager, United Zinc & Chem. Co., Kansas City, Mo.  
 position : Consulting Metallurgist.

e T. Hancock, Washington, D. C.  
 ed by E. W. Parker, George H. Ashley, George O. Smith.  
 1875, Tomah, Wis. 1896, Grad High School, Tomah, Wis. 1901, Grad. at  
 n University; B. S. degree. 1904, graduate work at Wisconsin University.  
 Wisconsin Geological and National History Survey. 1904-11, Taught Geology,  
 y and Applied Mining Geology in Michigan College of Mines. During this  
 k three extensive trips through the West studying most of the important mining  
 1911-13, U. S. Geological Survey.  
 position : Associate Geologist, U. S. Geological Survey.

ht Hasselbring, Magpie Mine, Ont.  
 ed by F. W. Sperr, Enoch Henderson, W. E. Hopper.  
 1883, Flint, Mich. 1901, Flint High School. 1906, Michigan College of Mines;  
 M. 1906-07, Engineer and Chemist at North Freedom, Wis., for International  
 Co. 1907-08, Mining engineer for Lake Superior Corporation. Mar.-Oct.,  
 nager of Mines for Wilbur Iron Ore Co. 1909, Diamond drilling. 1910, Supt.,  
 ne.  
 position : 1911 to date, General Supt. Mine Dept., Lake Superior Corporation.

Joseph Hirschberg, Corbin, Mont.  
 ed by Adelph Zimmerman, F. M. Smith, G. C. Riddell.  
 1889, Fort Benton, Mont. 1895-1906, Public and High Schools, Helena, Mont.  
 Michigan College of Mines, Houghton. 1909-10, six months post graduate;  
 Bachelor of Science and Engineer of Mines. 1910, Assayer with Ruby Gulch  
 o., Whitcombe, Mont. 1912, Engineer, Boston & Corbin Copper & Silver Min-  
 Corbin, Mont.  
 position : Mining Engineer, Boston & Corbin Copper & Silver Mining Co.

E Howard, Lockport, N. Y.  
 ed by Bradley Stoughton, Albert Sauveur, Herbert M. Boylston.  
 —, Grammar School only. Technical mostly self-taught. Short course in  
 esting Laboratories. 1893-97, New York Air Brake Co. 1897 to date, Simonds  
 uring Co.  
 position : Metallurgist and Chief Chemist, Simonds Manufacturing Co.

Johnston, Cobalt, Ontario, Canada.  
 ed by R. B. Watson, Samuel W. Cohen, R. H. Lyman.  
 1867, Johnstone, Scotland. Johnstone and Paisley public schools, science classes.  
 Apprenticeship as Mechanical Engineer with John McDowell and Sons, Johnstone,  
 1890-91, Clerk and Accountant, Standard Bank of So. Africa, Ltd., Cape  
 1891-1913, with Charles Butters in South Africa, United States, Mexico, Central  
 as Engineer and Manager of mining companies; during the past 15 years I have  
 onable for the erection and equipment of \$2,000,000 of Mining and Metallurgical  
 ons.  
 position : Metallurgical Engineer, Nipissing Mining Co., Ltd., Cobalt, Ont.

Atwood Kee, Cobalt, Ontario, Canada.  
 ed by R. B. Watson, Arthur A. Cole, R. H. Lyman.  
 1878, Port Henry, N. Y. Public Schools in Crown Point and Plattsburg, N. Y.  
 Mill Assay Offices at Combination Silver Mg. Co. and Granite-Bi-Metallic Mg.  
 psburg, Mont., as helper. 1893-95, Englehorn Business College, Helena, Mont.;  
 rg High School; Salt Lake City, Utah, High School. 1896, University Utah,  
 o City, Utah. 1900, Metal Mining Course, I. C. S. 1897-1900, Asst. Chemist  
 eyor, Utah Consolidated Mg. Co., Bingham, Utah. 1900-1902, Operated mine  
 leases on personal account, Bingham, Utah. 1902-06, Chemist and Foreman,  
 onsolidated Mg. Co., Bingham, Utah. 1906-06, General mill experience, Daly  
 Co., Park City, Utah. 1906-07, Mill Supt., Godiva Mg. Co., Eureka, Utah.  
 Mine Captain, Nipissing Mining Co., Ltd., Cobalt, Ontario, Canada. 1908-09,  
 , Newhouse Mines & Smelter Co., Newhouse, Utah.  
 position : 1909 to date, Supt., Nipissing Mining Co., Ltd., Cobalt, Ontario,

**George B. Koch, Altoona, Pa.**

Proposed by Hugh P. Tiemann, N. W. Zimmerschied, Bradley Stoughton.

Born, Altoona, Pa., 1870. 1891, Rensselaer Poly. Institute. 1892, P. R. R. Machine Shops. 1895, P. R. R. Test Dept., Foreman locomotive testing plant, Foreman physical laboratory. 1912, Asst. Genl. Foreman, P. R. R. Foundries.

Present position : General Foreman, P. R. R. Foundries.

**Herbert S. Kohlberg, Macdonald Mine, Weedon, Quebec, Canada.**

Proposed by J. F. Kemp, Charles Berkey, Alfred J. Moses.

Born, 1886, El Paso, Texas. Public School, El Paso. 1900-03, Oberreal Schule, Germany. 1903-09, Columbia University, B. S. College 1907, E. M. 1909. 1909, Surveying, etc., General Development Co., Miami Copper Co., New Planet Copper Co., Arizona. 1910, Surveyor, Ray Consolidated Copper Co. 1911, Maintenance Dept. on construction El Paso & Southwestern R. R. 1912, Engineer with Moctezuma Copper Co., Nacozari, Sonora, Mexico.

Present position : Asst. Supt., MacDonald Mine, East Canada Smelting Co., Weedon, Quebec, Canada.

**Frederick Charles March, London, England.**

Proposed by Herbert Youl.

Born, 1876, Westminster. 1892, Westminster, Special Course of Mathematics and Science. 1896-09, Railroad and General Engineering, Midland Works, Nottingham. Elected member Institution Mining Engineers, England. 1909-11, Managing Inglaterra Tin Mines, Spain.

Present position : Chief Engineer for Messrs. Harding Brothers, Ltd.

**Harry March, London, England.**

Proposed by Herbert Youl.

Born, 1869, Brighton, England. Special Mathematics and Science, Westminster. 1886-93, Training, Civil and Mech. Engineering, Globe Works, Sheffield. 1893-96, Training, Mining Engineering and Inorganic Chemistry. 1896-99, Practiced Mining Engineering; Manager, Julia Copper Mines, Spain, and Spanish Kaolin Estates. Specializing in mining radio-active ores in various parts of the world, mainly Portugal. 1907, Elected member of Institution Mining Engineers, England.

Present position : Mining radio-active ores, Portugal.

**John Eugene McCarthy, Denver, Colo.**

Proposed by F. W. McNair, F. W. Sperr, W. E. Hopper.

Born, 1888, O'Neil, Neb. 1903-07, East Denver High School, Denver. 1909-10, Michigan College of Mines, Houghton, Mich.; B. S. and E. M. 1910-11, Foreman, Mining Engineer, Kittimac Mines Co., Silverton, Colo. 1911-12, Mining Engineer and Asst. Supt., Hales Mining & Milling Co., Lake City, Colo. 1912, Manager, McCarthy Flotation System, Denver and Lake City, Colo.

Present position : 1912 to date, Oriental Mining Co., Lake City, Colo.

**Elmer Theodore McCleary, Youngstown, Ohio.**

Proposed by H. S. Braman, William E. Manning, C. J. Robinson.

Born, 1878, Pine Grove Furnace, Pa. 1895-97, Carlisle and Harrisburg, Pa., High Schools. 1901, Graduated Penn. State College, State College, Pa.; degree B. S. 1901, Diamond State Steel Co.; Chemist. 1901-06, Carnegie Steel Co. Ohio Works; Chemist and Blast Furnace Dept. 1906 to date, Youngstown Sheet & Tube Co.; Chief Chemist, Asst. Supt. Blast Furnace and Steel Depts., Asst. Genl. Supt.

Present position : Asst. Genl. Supt., Youngstown Sheet & Tube Co.

**Thurston Cables Merriman, Waterbury, Conn.**

Proposed by William H. Bassett, George L. Heath, John A. Capp.

Born, 1886, Bristol, Conn. 1892-1902, Bristol Grammar and High Schools. 1902-03, Torrington High School. 1905-09, Mass. Institute of Technology; S. B. in Dept. of Mining Engineering.

Present position : Asst. Metallurgist, American Brass Co., Waterbury, Conn.

**Professor G. A. F. Molengraaf, Delft, Holland.**

Proposed by J. F. Kemp, Charles P. Berkey, E. O. Hovey.

Prof. Geology, Ecole Polytechnique, Delft, Holland.

**Henry Jessup Packard, Port of Spain, Trinidad, B. W. I.**

Proposed by J. C. Branner, D. M. Folsom, G. H. Clevenger.

Born, Palmyra, N. Y., 1883. 1897-99, Palmyra High School, Palmyra, N. Y. 1905-07, Ontario High School, Ontario, Cal. 1908-11, Leland Stanford Junior University. A. B. in Mining and Metallurgy. 1912-13, Spring Valley Water Co., San Francisco, Cal., Geolo-

water measurer. Leland Stanford Junior University, Asst. Stanford Geological  
1913, Assayer, Oroyo Leonesa, Ltd., Matagalpa, Nicaragua. 1913, Caribbean  
n Co., Field Geologist.

position : Geologist, The Bermudez Co., Guanoco, Venezuela.

F. Pullen, Alexo Nickel Mine, Iroquois Falls, Ont., Canada.  
ed by Reginald E. Hore.

1880, Oakville, Ont. 1890-96, Public and High Schools. 1896-98, Trinity Col-  
ool. 1901-06, School Practical Science, University Toronto ; Grad. Mining En-  
g. 1902-03, Canadian Copper Co., Creighton Mine ; mucker, drill helper, asst.  
1906-12, Engineer on Location and Construction and Res. Engineer, Trans.  
Co., Cochran, Ont.

position : Manager and operator, Alexo Nickel Mines, Iroquois Falls, Ont.

Quigley, Westville, Cal.

ed by Thomas T. Read.

1860, Lancaster, Pa. 1876, Common School. 1876-77, Northern Illinois College,  
Ill. 1881-82, Assay office, Grand Union Smelter, Rico, Colo. 1883, Assayer and  
Santa Clara Mill, Rico, Colo. 1884-93, Miner, Foreman and Supt. of mines in  
County, Colo. 1893-1913, Owner, manager, supt., assayer, etc., of mines in  
a. Four years Supt. Herman Mine, Westville, Cal.

position : Manager and part owner, Black Canyon Mine, Westville, Cal.

Chandler Ray, 1235 Webster Street.

ed by D. M. Folsom, G. H. Clevenger, H. F. Bain.

1882, Duluth, Minn. Preparatory School, Montclair, N. J. 1903-06, Stanford  
ty, Geology and Mining. 1912-13, Stanford University. 1913-14, Advanced  
Ph. D. 1906-07, Mining and Surveying. 1908, Metallurgical work for Dorsey  
Pittsburg, Pa. 1909-12, Farming.

position : Advanced work in Geology for Ph. D. at Stanford University.

am Augustine Robertson, East Dedham, Mass.

ed by S. P. Sharples, W. E. C. Enstis, A. H. Eustis.

1864, East Boston, Mass. Chelsea Grammar School. Kelvin Copper Co., Kelvin,  
1900-03, Assayer and Promoter.

position : 1892 to date, Mgr. and Expert, Dedham Pottery Co. 1909 to date,  
st. and Treas., Boston and Washington Mining and Milling Co. 1911 to date,  
ngar Mining & Milling Co.

rd Charles Ryan, Toledo, Ohio.

ed by J. B. Read, A. W. Smith, Charles H. Fulton.

1890, Cleveland, Ohio, 1908-12, Case School of Applied Science, Cleveland ; B.  
ning Engineering. 1912, Scale car operator, Toledo Furnace. 1913, Stockhouse  
and blast furnace foreman at Toledo furnace. Member Pick & Shovel Club at Case

position : Blast furnace foreman, Toledo Furnace Co.

slaus Skowronski, Newark, N. J.

ed by Herman Garlichs, Edward Keller, K. W. McComas.

1881, Bex, Switzerland. 1904, B. S., Mass. Institute of Technology. 1904, Re-  
Rubber Co., Youngstown, Ohio. 1905-09, American Smelting & Refining Co.,  
N. J. 1909-12, C. L. Constant Co., New York City.

position : Research Chemist, Raritan Copper Works, Perth Amboy, N. J.

es Albert Smith, Natoma, Cal.

ed by F. R. Short, C. H. Munro, F. L. Morris.

1886, Philadelphia, Pa. 1912, Grad. University of California, Mining and Geology.  
Asst. Instructor University of California, Dept. of Physics.

position : Asst. Mining Engineer, Natomas Consolidated of Calif.

Sorge, Magdeburg-Buckau, Germany.

ed by Dr. K. Vogelsand, Rudolf Franke, Rudolf Hoffman.

1855, Zwickau, Germany. 1861-73, Public and High Schools, Zwickau, Chem-  
Dresden. 1873-77, School of Mines, Freiberg ; diploma Eisenhütteningenieur.  
Chemical Engineer, Illseder Hütte. 1879-81, Asst. Manager High Furnace  
eorgsmarienhütte. 1882-86, Manager Bessemer Dept. and Tire Rolling Mill Ona-  
Stahlwerk. 1886-88, Consulting Engineer in Metallurgical Dept. Carl Spaeter,  
1888-93, Genl. Mgr. Rombacher Hüttenwerke, Lorraine. 1893-99, Asst. of the  
ate of Fried Krupp, Essen-Ruhr.

position : 1899 to date, Member of the Directorate of Fried Krupp, Essen, and  
Manager of Krupp-Grusonwerk, Magdeburg.

**Eugene Stebinger, Washington, D. C.**

Proposed by G. O. Smith, G. H. Ashley, E. W. Parker.

Born, 1883, Portland, Ore. 1889-1902, Grammar and High Schools, Portland. 1902-05, University of California, College of Mines. 1906-07, University of Chicago; B. S. degree. 1905, Yellow Aster Mfg. Co., Ransburg, Cal. 1906, Copper Queen Mfg. Co., Bisbee, Ariz. 1907-13, U. S. Geol. Survey. 1910, five months, Normal College, New York.

Present position: Associate Geologist, U. S. Geological Survey.

**Rupert Kennedy Stockwell, Rancagua, Chile.**

Proposed by Robeson T. White, E. P. Fleming, B. T. Colley.

Born, 1882, Birdsell, N. Y. 1901-05, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; Draftsman and Checker. 1905, Morgan Engineering Co., Alliance, Ohio; Draftsman and Traveling Inspecting Engineer. 1906-1907, National Tube Co., McKeesport, Pa.; Original Design Rolling Mills and Steel Plants. 1908-10, Steptoe Valley Smelting Co., McGill, Nev.; in charge of Construction of Smelter and Concentrator. United States Smelting Co., Salt Lake City; Construction Engineer. 1910-11, Tennessee Copper Co., Copperhill, Tenn.; Asst. Chief Engineer, in charge building Smelter and Acid Plant. 1912, Robins Conveying Belt Co., New York City; in charge estimating and proposal designing.

Present position: Chief Engineer, Braden Copper Co., in charge design and construction, Smelter, Mill, Acid Plant, etc.

**William Huff Wagner, Santiago, Cuba.**

Proposed by G. W. Pfeiffer, Le B. B. Reifsnieder, Charles F. Rand.

Born, 1888, Pottsgrove, Pa. 1907, Grad., Carnegie, Pa., High School. 1912, Grad., Carnegie Institute of Technology, Pittsburgh, Pa.; Degree, B. S. in Mining Engineering. 1907, Rodman, Carnegie Coal Co., Carnegie, Pa. 1908, General surveying, Hope Gas Co., Clarksburg, W. Va. 1909, General surveying, Oliver Iron Mining Co., Hibbing, Minn. 1910-11, Chemist, United States Bureau of Standards, Pittsburgh, Pa. Chemist, Annabelle Coal & Coke Co., Annabelle, W. Va.

Present position: 1912 to date, Asst. Engineer, Spanish-American Iron Co.

**Myron L. Fuller, Boston, Mass.**

Proposed by Frederick G. Clapp, George H. Ashley, M. R. Campbell.

Born, 1873, Brockton, Mass. 1892-96, Mass. Institute of Technology, Grad. Course in Geology, degree B. S. 1896-99, Instructor in Geology in Mass. Institute of Technology. 1899-1907, Geologist with the U. S. Geological Survey, Chief Hydrologist in Water Resources Branch. 1907-11, Pres. M. L. Fuller Cranberry Co., Fuller-Hammond Co., etc.

Present position: 1912 to date, Managing Geologist, Engineering Division, The Associated Geological Engineers.

**Louis G. Huntley, Pittsburgh, Pa.**

Proposed by Frederick G. Clapp, Frederick Crabtree, C. T. Griswold.

Born, 1883, Michigan. 1908, Grad. Mining Engineering, Carnegie Institute of Technology, degree B. S. 1908-10, Mining Companies in Colombia and Ecuador.

Present position: 1911 to date, Geological Engineer with The Associated Geological Engineers.

**Lloyd B. Smith, Pittsburgh, Pa.**

Proposed by Frederick G. Clapp, Frederick Crabtree, C. T. Griswold.

Born, 1878, Laceyville, Pa. 1894, Mansfield Normal. 1902-7, Penn. State College, B. S. and M. S. degrees. 1905-9, Asst. Professor in Geology, Penn. State College. 1909-13, Instructor in Geology, Carnegie Institute of Technology.

Formerly a member of the Institute.

Present position: Geological Engineer with The Associated Geological Engineers.

### *Associate Members.*

**Herbert D. Hawks, New York City.**

Proposed by J. W. Allen, A. C. Carson, W. D. Thompson.

Born, 1874, Rochester, Ohio. 1892, Grad., Columbia School of Mines, Electrical Engineering course; Degree E. E. Asso. Member, American Institute Electrical Engineers. 1893-1912, Worked for General Electric Co. in various capacities, shop testing, construction, engineering, and commercial; last 10 years commercial engineer and salesman.

Present position: 1912 to date, Commercial engineer and salesman, United Metals Selling Co.



Carl Sweetland Reed, New York City.

Proposed by T. A. Gillespie, Charles F. Rand, E. T. Gray.

Born, 1884, West Bloomfield, N. Y. 1905, B. S. M. E., University of Wisconsin. Senior Member, American Society of Civil Engineers. 1905-06, Engineer in Experimental Dept. J. I. Case T. M. Co., Racine, Wis. 1906-07, Designer, F. M. Prescott Pump Co., Milwaukee, Wis. 1907-11, Engineer, and Salesman, and Western Representative, American Locomotive Co. 1912, Eastern Sales Manager, Bucyrus Co.

Present position : Vice-President, General Equipment Co.

### Junior Members.

Charles L. Annett, Boise, Idaho.

Proposed by R. S. McCaffery, C. A. Stewart, Francis Jenkins.

Born, 1885, Spencer, Iowa. 1909-13, Student in Mining at University of Idaho. 1911, 1912, 3 months each at Greyhound Mine, Custer County, Idaho. 1913, 3 months at Silver City Mining & Milling Co., Silver City, Idaho.

Present position : Student at Univ. of Idaho.

John William Johnson, Moscow, Idaho.

Proposed by R. S. McCaffery, C. A. Stewart, Francis Jenkins.

Born, 1886, Rexburg, Idaho. 1908, Underground work with Joe Dandy Mg. Co., Cripple Creek, Colo. 1911 and 1913, 3 months each with Federal Mining Co., Mullan, Idaho.

Present position : Senior student in Mining, University of Idaho.

Orville H. Pierce, Salt Lake, Utah.

Proposed by Robert H. Bradford, Robert S. Lewis.

Born, 1889, Nebraska. 1908-12, University of Nebraska ; A. B. 1912-13, Graduate Dept. of Geology, University of Nebraska. Summer, 1911, U. S. A. Water Supply, Yellowstone Natl. Park. Summer, 1912, U. S. Geological Survey Lignite Coal Fields, Wyoming, 1913, Nebraska Geological Survey.

Present position : Fellow, Utah School of Mines.

Bert F. Smith, Moscow, Idaho.

Proposed by R. S. McCaffery, C. A. Stewart, Francis Jenkins.

Born, 1889, Liverpool, England. Summers of 1907 to 1913 inclusive, Greyhound Mining & Milling Co., Ltd., Custer County, Idaho.

Present position : Senior Student in Mining at University of Idaho.

Walter Preston Scott, Moscow, Idaho.

Proposed by R. S. McCaffery, C. A. Stewart, Francis Jenkins.

Born, 1890, Trenton, Mo. 1912, Summer, Bunker Hill & Sullivan Mining Co., Kellogg, Idaho. 1913, 3 months underground work, Hecla Mining Co., Burke, Idaho.

Present position : Senior Student in Mining at the University of Idaho.

### CHANGES OF ADDRESS OF MEMBERS.

The following changes of address of members have been received at the Secretary's office during the month of October, 1913. This list, together with the lists published in *Bulletin* Nos. 76 to 82, April to October, 1913, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Mar. 1, 1913, and brings it up to the date of Nov. 1, 1913.

|                    |                                                         |
|--------------------|---------------------------------------------------------|
| DERSON, VICTOR C.  | 1043 Emerson St., Denver, Colo.                         |
| LEN, ROY H.        | Instructed to hold all mail.                            |
| EDEN, F. F.        | Jackson Iron & Steel Co., Jackson, Ohio.                |
| MAS, MILTIADIS TH. | 48 Blvd. Emile Augier 48, Paris (16e), France.          |
| CUR, GEORGE S.     | P. O. Box 16, Leadville, Colo.                          |
| CORN, FREDERICK W. | W. Austin, Mich.                                        |
| AL, LATHAM O.      | P. O. Box 370, Dunedin, New Zealand.                    |
| LLIN, CHARLES E.   | 744 Lincoln Parkway, Chicago, Ill.                      |
| BY, J. FRANCIS.    | The Reinforcement Co., 49 W. 27th St., New York, N. Y.  |
| DEAUX, A. F. J.    | 29 Rue Faucigny, Fribourg, Switzerland.                 |
| ADY, ADOLPHE F.    | Taylor Iron & Steel Co., 30 Church St., New York, N. Y. |
| ADY, JAMES.        | P. O. Box 38, Golden, B. C., Canada.                    |
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## Applied Geology in the Butte Mines.

BY FRANK A. LINFORTH, BUTTE, MONT.

(Butte Meeting, August, 1918.)

THE object of this paper is to present a brief outline of the methods geologic mapping employed in the Geological Department of the Anaconda Copper Mining Co., at Butte, and to show by means of a few typical examples the practical nature of the results obtained. The extremely complicated geological conditions early encountered in Butte mining led mine operators to realize the necessity of accurate detailed geologic mapping as an aid to successful development of ore bodies. The organization of the Anaconda Geological Department was undertaken in 1900 by H. V. Winchell, who, in conjunction with D. W. Brunton, worked out the essential methods and procedure which are, in the main, followed at the present time. Since the year 1906 the geologic work has been under the direction of Reno H. Sales, and in some respects the scope of the work has been slightly enlarged. An excellent article describing the general equipment of the geological department was presented by D. W. Brunton at the British Columbia meeting of the Institute in 1905.<sup>1</sup> The idea, that data collected underground and recorded should be put to practical use and not remain a mere "inventory of the company's underground possessions," is the keynote to the success of applied geology in Butte.

The geologic notes are taken as soon as possible after the ground is broken so that any mistake in the mining may be corrected at once, or any particularly advantageous procedure may be suggested before any useless work is done. Taking the notes underground is a comparatively simple matter, but a few necessary precautions may be pointed out. The essential to success is that the notes shall show exactly what geological facts are disclosed. The observer must discriminate carefully between important and unimportant exposures in making the record, especially as regards the relation between veins and stringers, between faults and minor slips, or between the characteristics of veins of different ages. A simple color scheme has been adopted for making this record. Red pencils are used to indicate

<sup>1</sup> *Trans.*, xxxvi., 508 (1905).

vein filling, which may be ore, barren pyrite, in fact any metallic minerals or quartz, and the record of the minerals present is found in the written notes. Blue coloring indicates evidence of faulting, either as the definite planes of movement or the crushed granite resulting from such movements. The sketches are always supplemented with copious notes as to the dip and strike, character of mineralization, and condition of the surrounding granite. A loose-leaf system has been adopted for the notes, which allows keeping them in the form of a card index. The scale used for the notes is 40 ft. to the inch, although 20 ft. to the inch is found to be a better scale in places where the detail is especially complicated.

In the office the principal working maps are drawn to a scale of 40 ft. to the inch. They are prepared on tracing cloth, one level to a sheet, and made to register perfectly with each other. The notes are platted on these sheets as soon as the surveys are posted, and the same color scheme is used as that for the original notes. After each platting, these maps are studied in conjunction with all the recorded data of that particular vicinity, and ideas for future development or for alterations of the present plan suggest themselves. The details studied on these maps, which often lead to useful suggestions underground, are such matters as the position of a block of drag ore at the intersection of a fault and a vein; the sudden change in the character of a vein; the relation of dip and strike of a vein to those of a fault cutting it, and the correlation of faults, veins, and ore shoots from level to level.

A set of maps drawn to a scale of 100 ft. to the inch is also maintained in the office for each mine. This scale makes it possible to show a whole mine level on one sheet without having it inconveniently large, and many useful correlations of faults and veins in widely separated parts of the same mine are made with this set. All the details consistent with the smaller scale are platted on these maps, although the written notes are usually not transferred from the larger working maps. Each mine foreman and superintendent is provided with a copy of the 100-scale geologic maps of his mine and has them posted from the office set at regular intervals.

Next in importance are the vertical cross-sections, of which Fig. 1 is typical. They are made on a scale of 100 ft. to the inch and are taken at various intervals along lines depending on the strike of the veins to be studied. Since the veins and faults in this district present such a variety of strikes, it is obvious that no cross section can be prepared which will cut all of them at right angles. Therefore, the true dip for a vein whose line of strike meets the plane of the

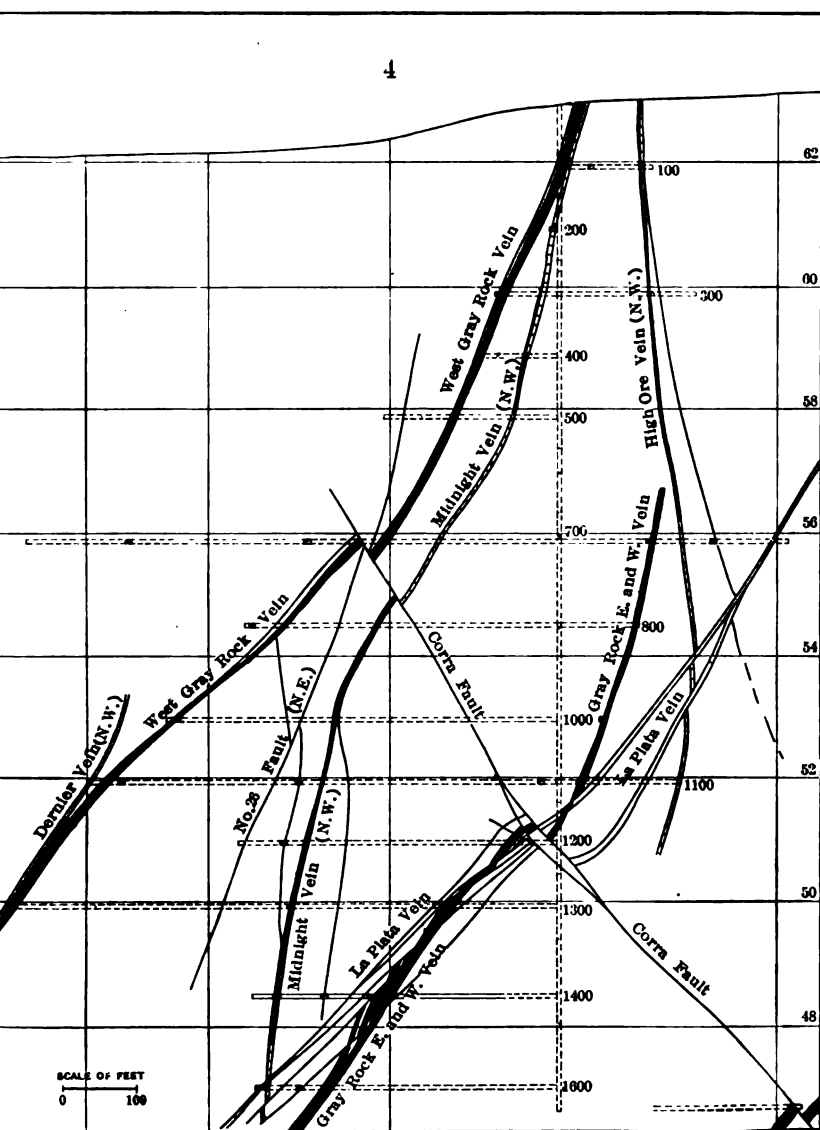


FIG. 1.—TYPICAL SECTION OF WEST GRAY ROCK MINE.

section at an acute angle cannot be used directly in making that section. In order that the geological relations on the section may be kept geometrically correct there is a convenient instrument in use which automatically reduces the true dip and angle of intersection to the angle of dip which must be plotted. Vertical sections have frequently been instrumental in clearing up complicated geological structure, and many savings and discoveries have been made by studying them.

There is also maintained in the office a set of 200-scale tracings covering the entire district. Only the principal geologic features appear on them, but the proper relative importance of the veins and faults is maintained. This set of maps is particularly useful in correlating and identifying veins in widely separated mines.

Before presenting examples of a few of the typical discoveries made through the aid of geologic maps and sections, some of the numerous minor uses of geologic information should be pointed out.

In laying out a certain drain tunnel on one of the lower levels where only limited development work had been done, it was found that the Bell fault would be encountered somewhere between the points to be connected. It was further noticed that the drain tunnel would meet the fault planes at an acute angle, and, since the fault zone is 75 ft. wide, the tunnel would have to lie within it for a distance of 320 ft. It was therefore decided to run the tunnel to a point as near as possible to the Bell fault without cutting it, then to cross-cut the fault at right angles and continue the work in the foot-wall of the fault. The problem for the Geological Department, then, was to locate the fault on this partly developed level as nearly as possible, and to turn the tunnel in accordance with the determined position. Several cross-sections and projections were made from the known positions of the fault, and these checked fairly well for the desired position. When the course of the tunnel was finally turned, the Bell fault was cut at right angles only 15 ft. from the turn. This work will result in a minimum cost of timbering and maintenance of this drain tunnel.

The pump stations in Butte are exceptionally large underground excavations, and it is desirable to locate them in ground which is as free as possible from faults and fault veins. The Geological Department has been called upon to make examinations for this purpose, and in one case it was found advantageous to change the location of one of these pump stations. The position originally selected for it would have been crossed by certain faults and much difficulty would have been met both in the excavation and in future maintenance.

Where a raise was designed to connect two levels, it has frequently been possible to select a starting point such that the raise would be continuous in ore, whereas in any other position it would have to cross a fault before reaching the level above. In the West Gray Rock mine, it was estimated by projections that the faulted segment of a certain vein between two faults would only be a few feet in length on the 800-ft. level. The development work at the time was limited on this level, and the calculations had to be made from positions known on the 1,000-ft. level, where the faulted segment was considerably longer. In order to make the raise in ore continuously from the 1,000- to the 800-ft. level, it had to be placed in accordance with these calculations. The result was entirely successful, and the raise through this wedge-shaped block of ore reached the 800-ft. level at its very apex.

In another case, the geologic cross-sections and plans showed that the La Plata fault was nearly parallel in strike to an east-and-west vein. The dip of the vein, however, was steeper than that of the fault, so that in the stopes the fault generally encroached upon the work and presented all the appearance of a hanging-wall of the vein. The stope became narrower and the operators considered it a pinched place in the vein. The stope would probably never have reached the level above if the geologic conditions had not been understood. When the ore was finally cut off raises were continued from the top of the stope, but designed to cross through the fault and make the fault a foot-wall rather than a hanging-wall. By this means, the ore above the fault was encountered at its lowest point and the stope continued to the level above. This procedure underground was suggested by studying that portion of the section, Fig. 1, which shows the La Plata fault and the Gray Rock east-and-west vein between the 1,200- and the 1,300-ft. levels. Fig. 1 is a cross-section through the West Gray Rock mine, and is typical of the 100-scale cuts of sections carried for all the mines.

An important discovery made through a somewhat different agency is represented in Fig. 2. The main drawing is a portion of the 40-ft. scale map of the 1,800-ft. level of the Mountain Con mine, and the small sketch is a reproduction of the 20-ft. scale notes upon which the discovery was made. It will be seen that without any geologic notes the drift No. 1824 would appear to be a drift on a continuous vein, and in fact it was stoped as such. The notes, however, displayed a significant difference in character between the westerly end, from which the work progressed, and the easterly end. The notation on the map indicates this difference. The westerly

portion exhibited the character of a quartz-pyrite vein, which it was known to be, but as the drifting continued the exposures were characteristic of the northwest fault vein system, notwithstanding the apparent continuity of the vein. This led to an investigation of the stope and the small sketch here reproduced was made. It showed these differences clearly to the geologist, and also the departure from the stope of the clay portions of the fault. Accordingly, the cross-cut No. 1869 was run, and it encountered the faulted portion of the quartz-pyrite vein now being mined in drift No. 1828. As this drift

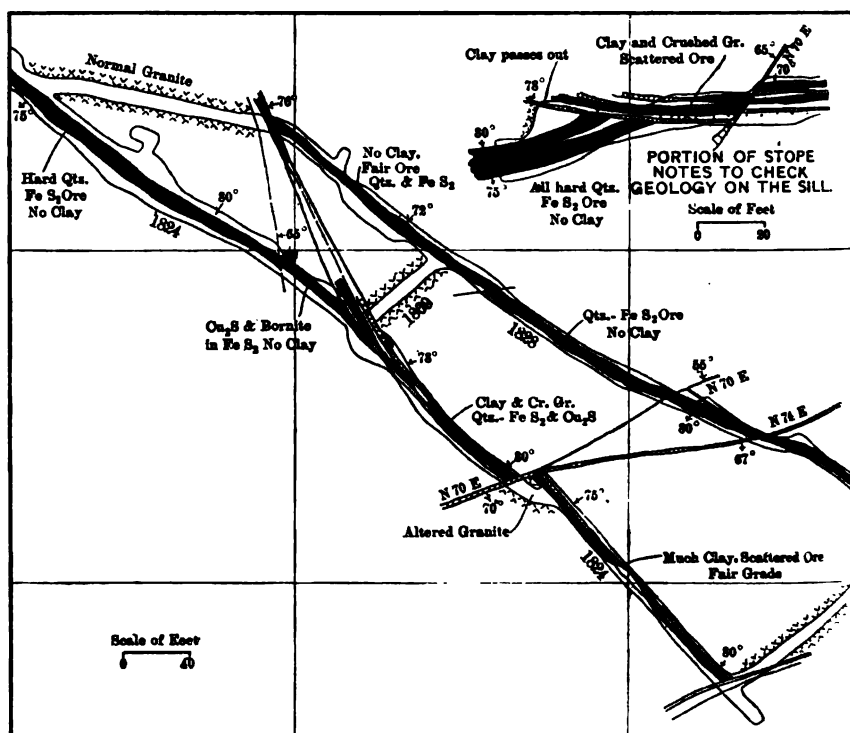


FIG. 2.—PORTION OF 1,800-FT. LEVEL, MOUNTAIN CON MINE.

was advanced westerly it intersected the fault vein as shown, and proved the correctness of the theory. After this discovery, the development of several other levels became merely a matter of projection.

Fig. 3 represents a portion of the 40-ft. scale maps of the 1,100- and 1,200-ft. levels of the West Gray Rock mine. It will be seen that the south-dipping east-and-west vein on the 1,100-ft. level lies north of the north-dipping Corra fault, while on the 1,200-ft level

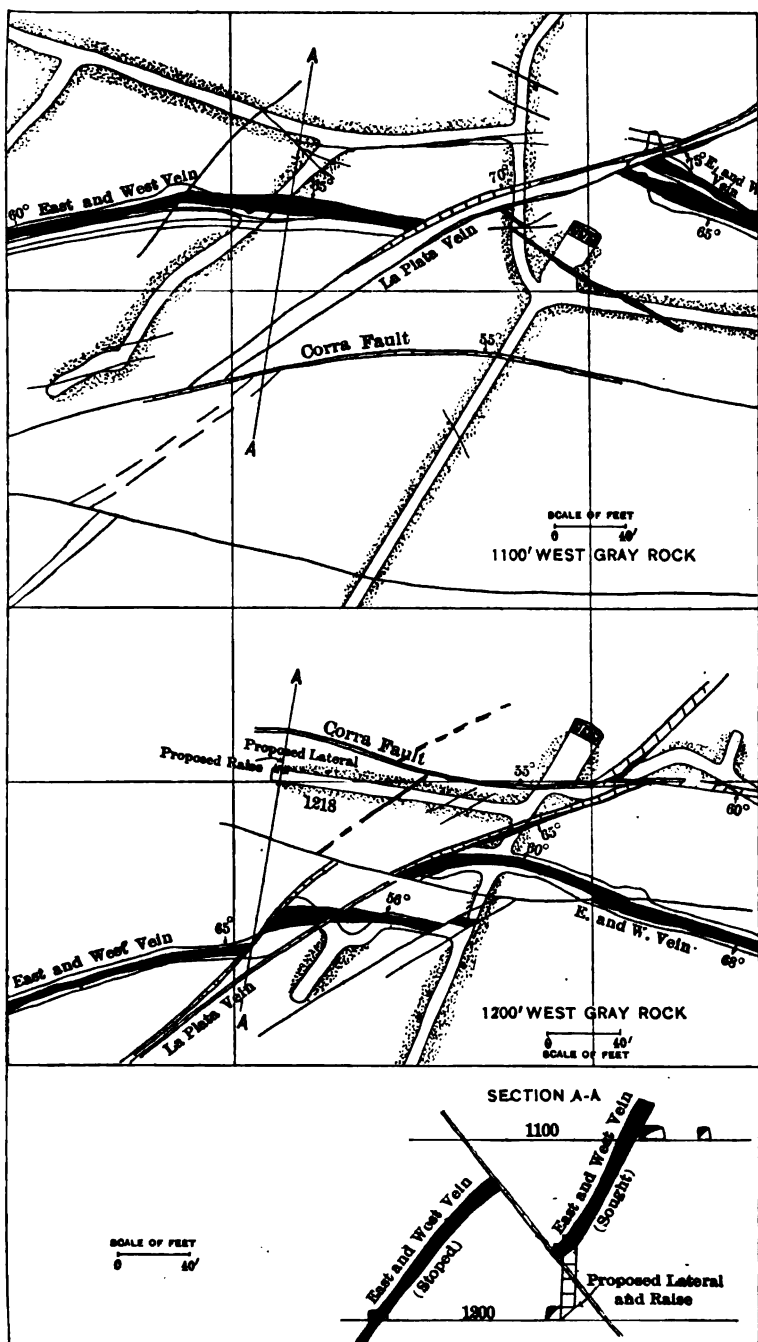


FIG. 3.—PORTION OF 1,100- AND 1,200-FT. LEVELS, WEST GRAY ROCK MINE.

these positions are reversed. The cross-sections clearly showed a displacement of the vein by the fault. The ore above the 1,100-ft. level was stoped to the 1,000 continuously in good ore and a stope was being worked above the 1,200, but, as shown on the maps, this stope could not reach the 1,100 on account of the fault. The ore on the 1,100 did not come down to the 1,200, for the same reason. The small section *A-A* shows these relations. It was therefore required to determine a point on the 1,200 from which a vertical raise could be run to intersect the vein as nearly as possible at its line of intersection with the fault. In other words, a vertical raise was to be so located as to reach the very bottom of the ore below the 1,100. A large-scale cross-section was drawn, making due allowance for the drag ore near the fault, and a course was given to the surveyor for the lateral drift No. 1218 in accordance with this section. The raise was to have one offset from the sill and to be vertical. The result of the work is shown in the small section in Fig. 3. Practically the bottom of the ore was encountered in this raise.

In Fig. 4 there is reproduced a portion of the 100-ft. scale maps of three levels of the High Ore mine, also a portion of the 40-ft. scale notes which led to the proper development of these levels. The map marked 300 Modoc shows a wide vein of good ore known as the Modoc vein. It was supposed that the entire drift was on this vein until the geologic notes showed that such was not the case. The portion near the shaft was barren; and the dip shown there was opposite to that at the east end. Bands of fault clay passed out of the drift as shown in the notes. It was decided that there were two veins exposed in this drift. At this time the drift on the level below (700 High Ore, see Fig. 4) had been abandoned at the point *C*. By carefully projecting the Modoc vein with its south dip from the 300 Modoc and also the other vein which is called the Edith May with its north dip, it was found that the line of intersection of these two veins would cross the level of the 700 High Ore at a point beyond the face of the old drift. Drifting was therefore continued in order to reach this determined point, and a certain amount of the north wall of the Edith May vein was broken so as to see the ground north of it. Within a few feet of the predicted intersection the Modoc vein was found and was stoped continuously to the level above. The next move naturally was to get the faulted portion south of the Edith May vein, which was accomplished as shown on the map. This information could now be extended to the next level below. The development work on the 900 High Ore had only reached the point *D*. Fig. 4, but the line of intersection of the Modoc vein and the Edith



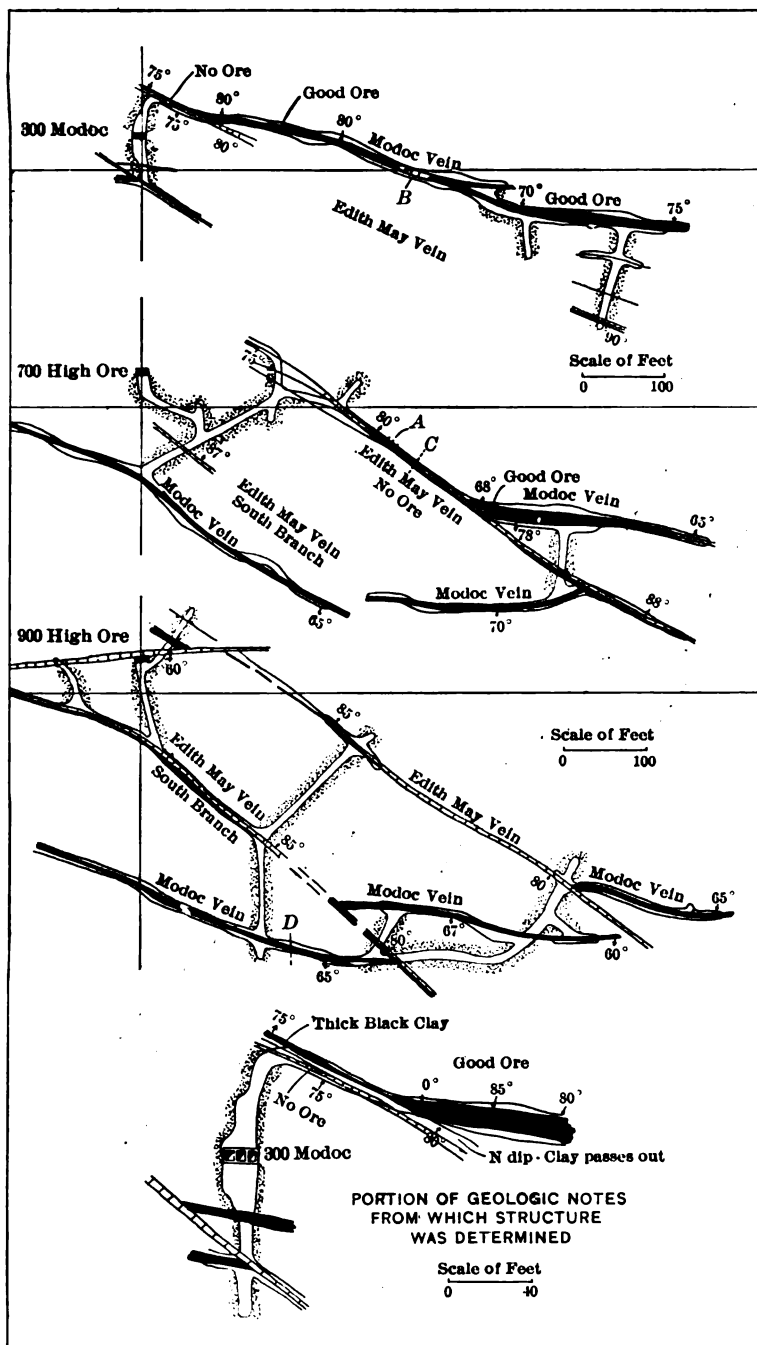


FIG. 4.—SECTION OF THREE LEVELS OF THE HIGH ORE MINE.

May vein was now well known on two levels and in the stopes, so it could be carried to the 900 with considerable accuracy. The underground work was therefore continued on the 900 with this point in view, and the map shows the accuracy with which the intersection was located. Nearly all of the ore thus developed on these three levels has been stoped.

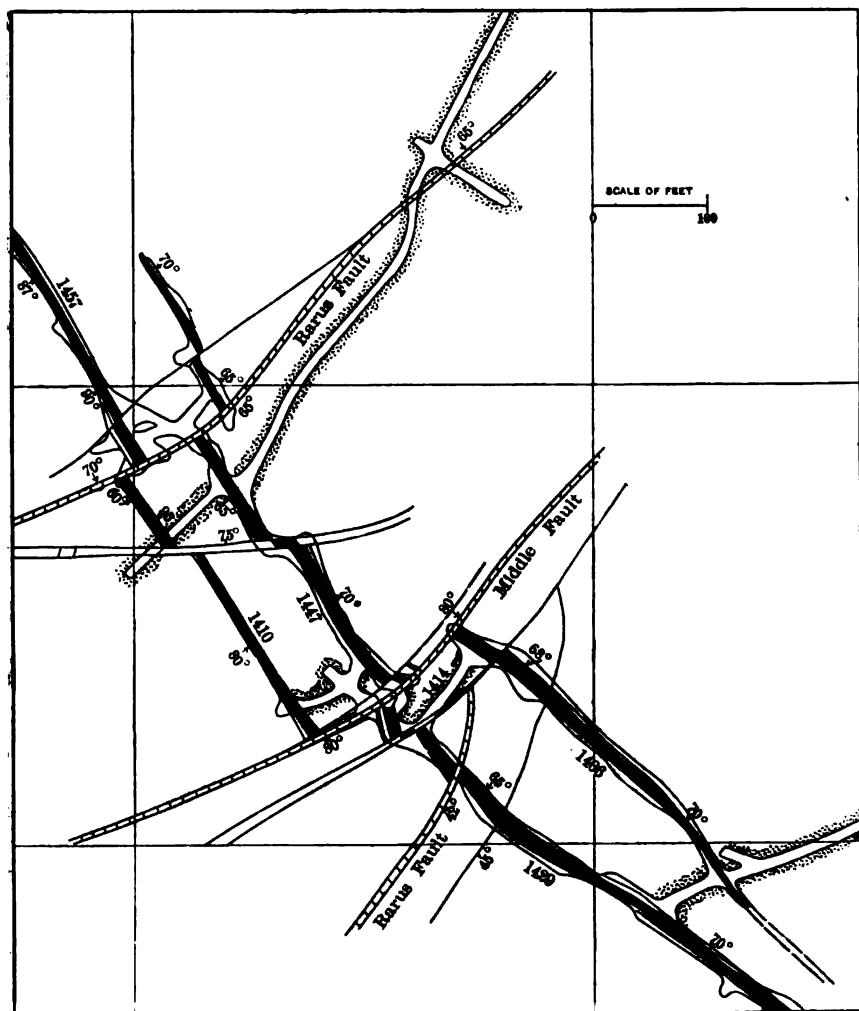


FIG. 5.—PORTION OF 1,400-FT. LEVEL, MOUNTAIN VIEW MINE.

In Fig. 5 is shown a portion of the 100-ft. scale map of the 1,400 level of the Mountain View mine. In order to understand the geologic work done in this case, the reader's attention must be called to drifts Nos. 1429, and 1447. The remaining numbered drifts

had not been run until the ore in them was discovered through the application of geologic knowledge of the conditions. The veins discovered in these first drifts were considered to be faulted segments of same vein. Later, however, in correlating with other parts of mine, the Middle Fault (see Fig. 5) was identified, but the direction of the throw on this fault was known to be to the left instead of the right, as the former interpretation would require. Therefore, drift No. 1447 must contain the faulted portion of a vein lying north of No. 1429, and further, the faulted segment of No. 1429 must be south of No. 1447. The map shows that this reasoning was correct, as the missing portions of the vein were found in drifts Nos. 1406 and 1410, respectively. The next step was to reach the south side above the Rarus Fault (see Fig. 5), which was done in drift No. 1457. Thus everything was accounted for, and three valuable ore bodies were won.

The examples of geologic work given above are typical of the work carried on in the Butte mines, although many more might be cited. Of course, all of the suggestions made by the Geological Department do not result in the discovery of ore bodies, but a failure to find the ore as predicted is unusual. When the underground work reaches a point as predicted, but cuts it in a barren place, calculations on the thickness of the ore shoot in the plane of the vein are made, and the downward extensions of such shoots have been located.

Graphic determinations of the direction and amount of movement on the planes of the principal faults have been made, and the knowledge of these displacements, both vertically and horizontally, is very helpful in locating faulted veins, or identifying faulted segments of veins. It has been recognized that the amount of horizontal displacement of several veins by any particular fault may vary considerably, and this variation has been studied graphically. The relation between the amount of horizontal displacement, on one hand, to the dip of the fault and vein and the angle between their strikes, on the other hand, has been studied, and has resulted in useful deductions. In order to show the variety of horizontal displacements possible on a fault, owing to differences in angles of dip and angles of intersection, Fig. 6 has been prepared. The four diagrams represent the four possible cases, namely:

- A. Dip of fault steeper than dip of vein, but in opposite direction.
  - B. Dip of fault flatter than dip of vein, but in opposite direction.
  - C. Dip of fault flatter than dip of vein, but in same direction.
  - D. Dip of fault steeper than dip of vein, but in same direction.
- In all cases a normal downward displacement of 100 ft. is assumed

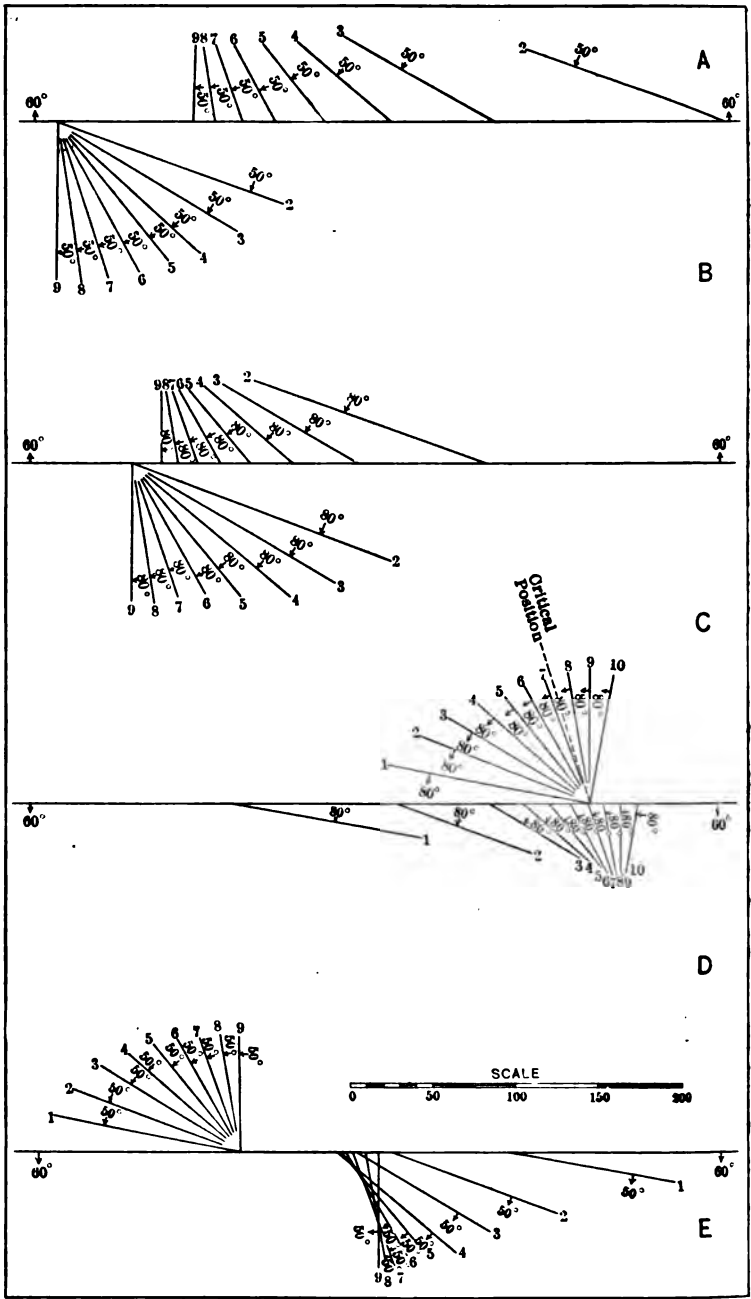


FIG. 6.—HORIZONTAL DISPLACEMENT OF VEINS BY FAULTING.

and the veins meet the fault at angles of from  $10^{\circ}$  to  $90^{\circ}$ . The various directions and amounts of horizontal displacement are shown. In one case it will be seen that the horizontal throw increases positively in one direction to a maximum, and then becomes negative. The angle of intersection of the vein with the fault that gives the turning point is called the critical angle, and a means of determining it graphically for any set of dips has been devised. It must be understood, however, that these graphical determinations have their limitations and must be applied accordingly.

Although this paper has dealt largely with problems related to structural matters in the Butte district, much attention is given to the study of the complicated mineralogical and chemical problems involved, but they fall beyond the scope of this paper.

#### DISCUSSION.

B. H. DUNSHEE, Butte, Mont.:—I merely want to testify to the value of the Geological Department so far as the Anaconda Copper Mining Co. is concerned. The information that the mining men get from the Geological Department is exceedingly valuable. Many times in mining underground we come to a question that is obscure; we don't know exactly where we are or what to do. Instead of going on blindly and perhaps wasting time and money searching for the continuation of the vein, we merely go to the Geological Department, and the geologists come to our assistance, and almost every time their conclusions are correct; the work they do is intelligent, and again I want to testify to the value of the accurate maps of the veins and fault systems as worked out by our Geological Department.



## Lead-Silver Mines of Gilmore, Lemhi County, Idaho.

BY RALPH NICHOLS, GILMORE, IDAHO.

(Butte Meeting, August, 1913.)

THE mines are near the town of Gilmore, in the Texas mining district. This district was organized in 1880. The present producing mines are near the terminus of the Gilmore & Pittsburg railroad. This railroad connects with the main line of the Oregon Short Line at Armstead, Mont. The distance from Gilmore to Armstead is 9 miles.

The town of Gilmore is near the head of the Lemhi river at an elevation of 7,000 ft., while the mines are from 400 to 1,300 ft. higher. The range of mountains upon which the mines are situated forms the watershed for the Little Lost river on the west and the Lemhi river on the east. The winters are severe and the snow fall is heavy, but the mines ship right through the year. There is an abundance of lumber suitable for all mining purposes in the immediate vicinity. Water is piped into the camp from a lake about 2.5 miles distant. This lake is about 1,400 ft. above the town of Gilmore. The water is exceptionally good for boiler and domestic purposes.

The mining companies now producing are the Pittsburg Idaho Co., Ltd.; the Latest Out Mining & Smelting Co., Ltd.; and the Gilmore Mining Co., Ltd. Besides the above properties, there are a number of prospects in different stages of development.

The producing mines of the district are fissures in limestone, with a general northeast-southwest course and a dip to the west of from 0° to 70°. These fissures are at about right angles to the bedding of the limestones. The veins are regular and the ore shoots strong, both laterally and in depth, so far as developed. The ore shoots have a strike or pitch to the south. The character of the formation is shown in Fig. 1, a section of the Latest Out mine.

### *Character of Ore.*

The ores of the district are oxidized, carrying an excess of iron over the silica (insoluble matter). The vein filling is a mixture of monite and hematite, which is replaced by shoots of lead-silver ores. The lead minerals consist of carbonate of lead principally, but with small quantities of sulphide, sulphate, and other lead minerals.

One peculiar feature noticeable in these properties is that the sulphides have gradually decreased with depth. For example, the ore from the upper workings down to 200 ft. in depth would be represented by the following:

| Lead.<br>Per Cent. | Silica.<br>Per Cent. | Iron.<br>Per Cent. | Zinc.<br>Per Cent. | Silver.<br>Oz. per Ton. | Gold.<br>Oz. per Ton. | Sulphur.<br>Per Cent. |
|--------------------|----------------------|--------------------|--------------------|-------------------------|-----------------------|-----------------------|
| 35                 | 20                   | 10                 | 7                  | 16                      | 0.025                 | 0.8                   |

The ore below the 200-ft. level and down to 500 ft. would be represented by the following:

| Lead.<br>Per Cent. | Silica.<br>Per Cent. | Iron.<br>Per Cent. | Zinc.<br>Per Cent. | Silver.<br>Oz. per Ton. | Gold.<br>Oz. per Ton. | Sulphur.<br>Per Cent. |
|--------------------|----------------------|--------------------|--------------------|-------------------------|-----------------------|-----------------------|
| 32                 | 10                   | 25                 | 3                  | 12                      | 0.025                 | 0.03                  |

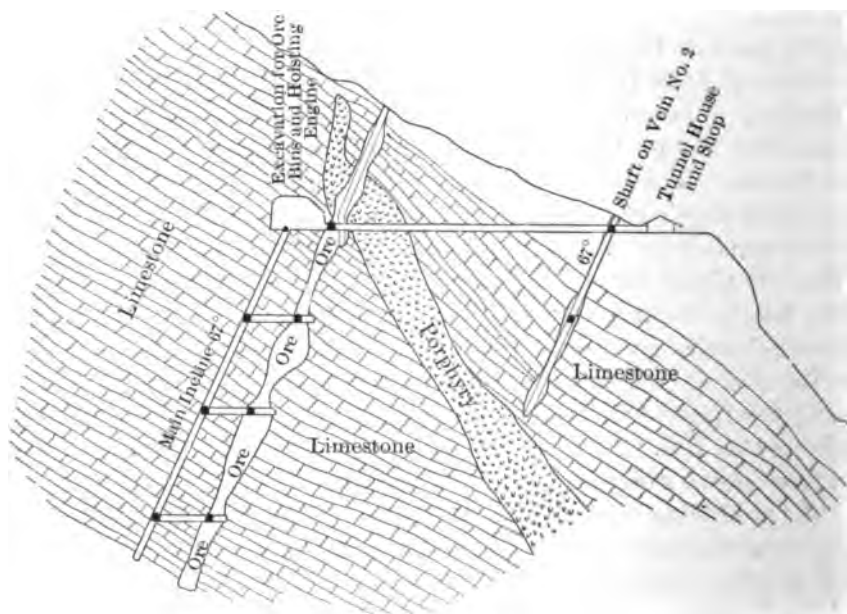


FIG. 1.—SECTION OF LATEST OUT MINE.

From the above comparison it will be seen that there is a slight falling off in lead and silver contents with depth. It will be noticed too that there is a smaller quantity of zinc, silica, and sulphur present, with a decided increase in iron content, making the ore a most desirable smelting ore, and it naturally commands a good price in the Salt Lake markets, where such ores are scarce. The ore is mined in bulk, requiring no concentration or assorting.



*Ore Occurrence.*

As before stated, the fissures are very regular, but the filling of the vein is a replacement of the limestone on either side of the fissure and sometimes reaches widths of clean ore of from 30 to 40 ft. The vein filling is a mixture of limonite and hematite replaced by shoots of lead minerals. The change from lead to iron content is generally very abrupt, so that it is not difficult to break the ore very clean. The ore is generally shipped in barge lots of from 50 to 500 tons (from one to ten railroad cars) and the lead content varies from 25 to 40 per cent.

*History.*

The first discoveries in the Texas mining district were made in the year 1880, and at that time little work was done, as the mines were then 80 miles distant from the nearest railroad shipping point (Pocatello).

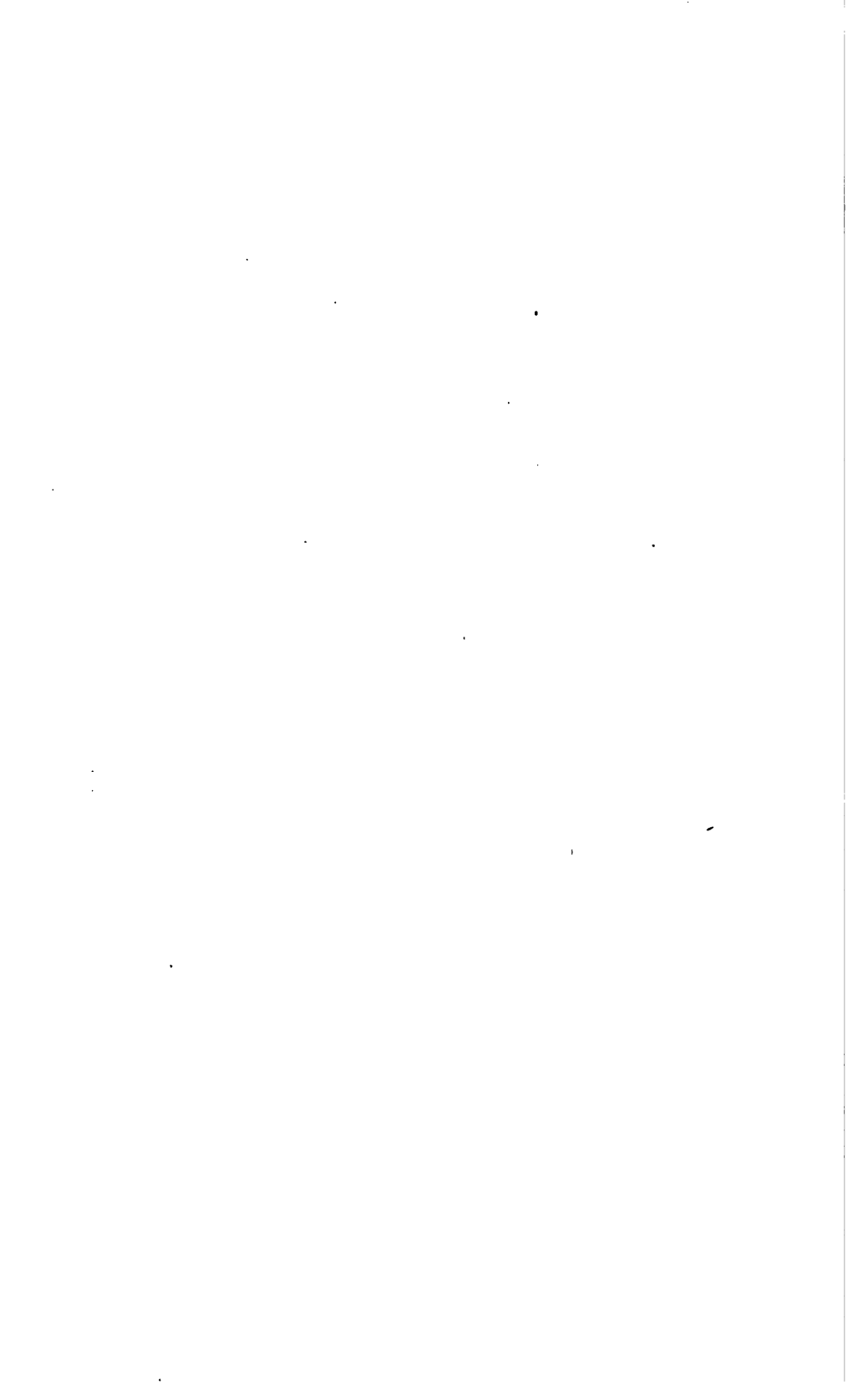
Later, however, in 1886, The Viola Mining & Smelting Co., of Pocatello, Idaho, erected its smelting plant and bought the ores from the Texas district, which gave quite an impetus to prospecting in this section. This smelting plant was successfully operated for about ten years, when the ores of the Viola mine were exhausted and the mines of the district shut down on their work and did little more than the annual assessment work.

In the year 1908 the building of the Gilmore & Pittsburg railroad was assured and at that time the work of developing the leading mines of this section was renewed.

Shipments were resumed in 1910, and from that time to the present the three properties mentioned have collectively shipped more than 100,000 tons of ore. Of the above amount, the Pittsburg Idaho Co., Ltd., has shipped about 75,000 tons; the Latest Out Mining & Smelting Co., Ltd., has shipped about 27,000 tons; and the Gilmore Mining Co., Ltd., has shipped about 1,200 tons of ore carrying gold values averaging about \$12 per ton and an excess of iron over silica of 40 per cent.

The lode being worked upon the Gilmore property contains only a very small quantity of lead and in this respect is quite unlike the other lodes in this district.

When one considers the short time that these properties have been worked and the small amount of development work done upon them the yield has been most satisfactory.



## The Electrification of the Butte, Anaconda & Pacific Railway.

BY R. E. WADE,\* ANACONDA, MONT.

(Butte Meeting, August, 1918.)

THE Butte, Anaconda & Pacific electrification is of peculiar interest, in an incidental way, to the entire mining fraternity, and especially the engineering branch, not only in this great Northwest country but throughout the entire Western mining country, which is rich in minerals and water power. It is probably fair to say that the prime object of mining and smelting engineering is to reduce the cost of production, and in the case in hand the relative location of mines and smelter brings the cost of transportation of ore to the front. While one might assign this item to the railway people, it is inseparably a part and parcel of the general scheme of the production of metal from the ore. In considering the electrification of the B., A. & P. railway the mining and smelting engineer, above all, wants to know what saving will be effected by the change in motive power. Unfortunately the new power has been in use during a very limited period and on the Smelter Hill section of the road only, and no reliable data, from actual service conditions, can be obtained until the entire electrified section has been in service for a reasonable length of time. My remarks on this subject at the present time, therefore, must of necessity be general in nature and more or less descriptive.

The railway, electrical and mining worlds and the country in general are indebted to the B., A. & P. railway for the pioneer work it is now doing, as it undoubtedly marks the beginning of the electrification, within the comparatively near future, of all transcontinental roads between the Missouri river and the Pacific coast. Together with this goes the development of an untold wealth in water power and all natural resources within the same territory.

For the first time in the history of electric railway work, in this country, direct current at a potential of 2,400 volts is being used. With this potential there is a great saving in transmission of energy to the locomotives and there are only two substations, one at either end and 26 miles apart, for supplying the power for the movement of trains of heavy tonnage over the main line and for switching movements at terminal and intermediate yards, and comparatively little feeder copper is required.

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\* Non-member.

The section of line that is being electrified lies between the receiving and distributing yard on Butte Hill and the concentrator bins at the Washoe smelter, Anaconda, together with the yards and tracks in the vicinity of the Butte passenger station, the Anaconda station and shops, the various departments of the smelter and the intermediate yards and sidings. It comprises about 30 miles of main-line single track, which, together with the various yards and sidings, makes up a total of about 90 miles on a single-track basis. The haulage of copper ore from the Butte mines to the smelter at Anaconda, which is the principal traffic, together with mine supplies, lumber, etc., moving in both directions, amounts to practically 5,000,000 tons of freight per year, or an average of 13,700 tons daily. The freight trains on the main line, weighing 3,400 tons and made up of 50 loaded ore cars, will be handled against a ruling grade of 0.3 per cent. Those on the Smelter Hill line, weighing from 1,350 to 1,400 tons and made up of 20 or more loaded ore cars, against a grade of 1.1 per cent., and those on the Butte Hill line, weighing from 750 to 800 tons and made up of empty ore cars and loaded supply cars, against a grade of 2.5 per cent., will be handled by locomotives consisting of two units. Single units will be used for making up trains in the yards and for spotting cars. Two of the units coupled to a loaded ore train are shown in Fig. 1, which also shows the overhead construction.

It may be interesting to note, as a matter of comparison between steam and electric motive power, that whereas in transporting ore between the East Anaconda yard and the concentrator bins, a distance of 7.25 miles against a grade of 1.1 per cent., the heavy steam locomotives require from 50 to 55 min. to make the trip with 16 cars of ore, a pair of electric locomotive units is making this same trip in 24 min. with 20 car loads of ore. In other words, the electric locomotive handles 25 per cent. more tonnage and consumes about one-half the time required by the steam locomotive.

The initial equipment consists of 17 locomotive units, 15 for freight and two for passenger service. Each weighs approximately 80 tons. When two units are coupled together they are operated in multiple from one master controller and they will haul the 3,400-ton train at a maximum speed of 15 miles per hour against the 0.3 per cent. grade and at 21 miles per hour on tangent level track. The same two units will haul the 1,400-ton train against the 1.1 per cent. grade at 17.5 miles per hour. The passenger locomotives are the same design as the freight locomotives except that they are geared for a maximum speed of 45 miles per hour on tangent level track. The

average passenger train is composed of one locomotive unit and three standard passenger coaches. The general design of the locomotives is of the articulated double-truck type, all weight being on the drivers. The cab is of the box type, extending the entire length of the loco-

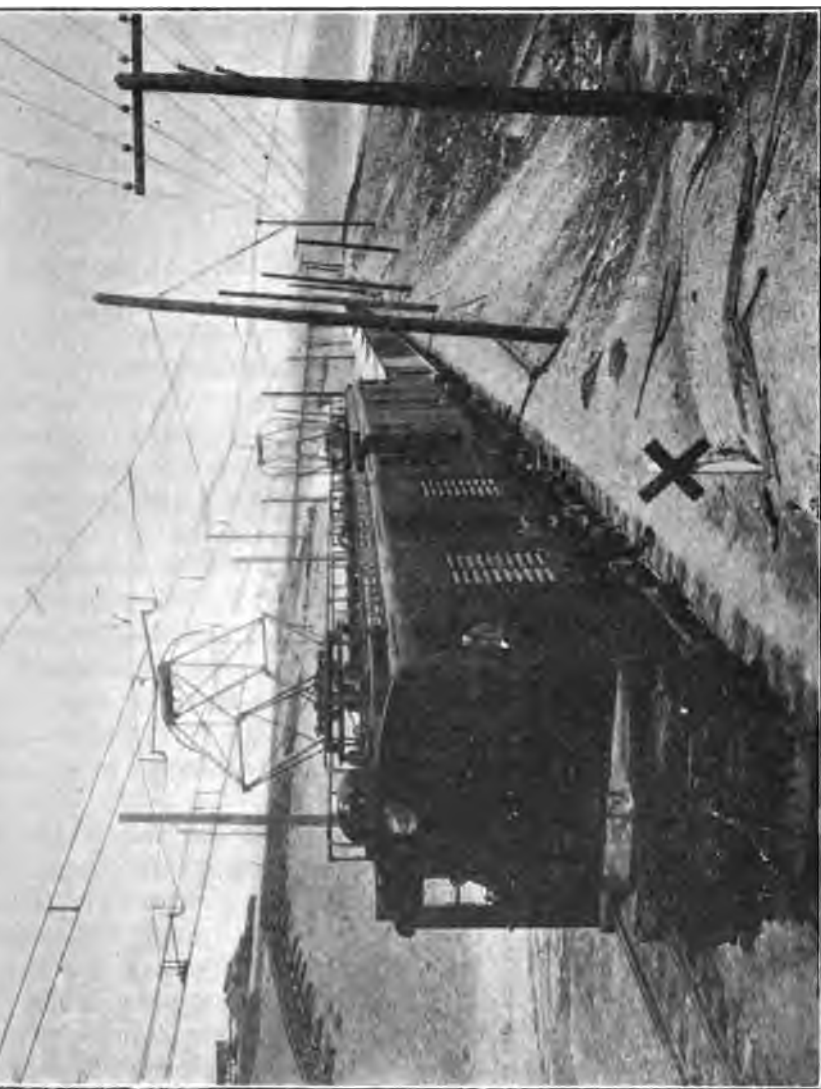


FIG. 1.—ELECTRIC LOCOMOTIVE IN USE ON THE BUTTE, ANACONDA & PACIFIC RAILWAY.

otive, and is of steel construction throughout. It is divided into three compartments, the center compartment containing the control apparatus, air compressor, and dynamotor, the latter for furnishing 110 volts for lights, air compressor, and operation of control circuit.

The two end compartments are for the accommodation of the engineer and contain the usual master controller, brake valves, and sand boxes. In addition, there is apparatus for ringing the bell and sanding by compressed air, and raising and lowering the pantograph trolley.

The principal data and dimensions applying to the locomotives are as follows:

|                                                        |              |
|--------------------------------------------------------|--------------|
| Length inside of knuckles.....                         | 37 ft. 4 in. |
| Height with trolley down.....                          | 15 ft. 6 in. |
| Width over all.....                                    | 10 ft. 0 in. |
| Total wheel base .....                                 | 26 ft. 0 in. |
| Rigid wheel base.....                                  | 8 ft. 8 in.  |
| Total weight.....                                      | 160,000 lb.  |
| Wheels, diameter .....                                 | 46 in.       |
| Tractive effort at $\pm 0$ per cent. co-efficient..... | 48,000 lb.   |
| Tractive effort at one-hour rating.....                | 30,000 lb.   |
| Tractive effort at continuous rating.....              | 25,000 lb.   |

The motors are of the GE-229-A commutating-pole type, wound for 1,200 volts and insulated for 2,400 volts. A forged pinion is mounted on each end of the armature shaft and meshes into a corresponding gear mounted on the wheel hub, providing a gear reduction of 4.84 on the freight locomotives and 3.2 on the passenger locomotives. The motor is designed especially for locomotive service, is inclosed, and provided with forced ventilation. Air is circulated over the armature and field coils and over and through the commutator, through longitudinal holes in the armature core, and thence exhausted through openings in the bearing head. The continuous capacity of each motor is 190 amperes on 1,200 volts under forced ventilation, and the input is 225 amperes on 1,200 volts for the one-hour rating. For the double unit the continuous rating is equivalent to an output of 2,100 h.p.

Current is collected by overhead trolleys of the pantograph type. They are pneumatically operated, and can be put into service from either engineer's compartment by hand-operated valve. The current collector proper consists of a roller made of steel tubing 5 in. outside diameter by 24 in. long, instead of the fixed or sliding pan usually employed for this purpose with the pantograph trolley. When two units are coupled together the trolleys are connected by couplers between the two units so that current may be obtained from both trolleys or from a single trolley, as may be desired.

The passenger coaches are to be heated by hot air, the air being forced through electrically heated coils by a motor-driven blower, 2,400-volt current being used for both heating coils and blower motor. The current for lighting passenger coaches will be taken

from the dynamotor in the passenger locomotive at a pressure of 600 volts.

The apparatus in each of the two substations consists of two motor-generator sets, each consisting of a synchronous motor directly connected to two 1,200-volt D. C. generators, the latter being connected in series to give the 2,400-volt line potential, together with two motor-driven exciter sets and the necessary switch board panels and control apparatus, most of which has been specially designed for this work.

Within the last few years electric railway engineers and operating people have been made to realize that the overhead-contact system is as important as, if not more important than, any detail of the system. This is on account of the fact that with locomotives and substations it is possible to hold units in reserve for emergency use, whereas with the overhead-contact system there is no such thing as reserve capacity. Furthermore, the contact system, if properly designed and built, is a permanent way equal in importance to the track and road bed. With the exception of using wood poles for supports, on account of the plentiful local supply, it is believed that the B., A. & P. railway is about as near permanency in its overhead construction as can be expected at the present stage of the art. The authorities differ as to the use of a rigid type of construction as compared with one which is flexible, though the majority agree that until we can construct a perfect track and road bed the flexible overhead-contact system is far superior to the rigid type. The engineers of the B., A. & P. railway adopted the flexible construction, which is of the catenary type, with 0.5-in. Seimens-Martin galvanized strand for messenger and 4/0 grooved copper trolley wire for contact member, the trolley wire being hung from the messenger by specially designed loop hangers which permit absolute freedom in vertical movement of trolley wire when subjected to pressure imposed by pantograph trolley. It is believed that on the main line, where operating conditions require relatively high speed, they have the only contact wire in this country which can be truly classified as flexible, and which is practically free from changes in flexibility, with consequent damage to contact wire from current-collecting devices.

The various yards and sidings included in the electrified section contain 300 track switches, calling for a corresponding number of overhead special work devices. Heretofore it has been customary to make use of grids or other devices, known as deflectors, for insuring the safe transition of the current collector from main line to siding or the reverse. On this work these devices, which are expensive to install and maintain, have been dispensed with and such transition is

taken care of by holding the contact wires parallel and in the same plane for a certain distance and raising the turn-out wire at the end so as to give a gradual approach to level of main line wire and current collector.

One of the great problems in connection with the overhead-contact system has been to take care of the expansion and contraction of various members due to changes in temperature and the fact that copper and steel, with their different temperature coefficients, make up the main members of the structure. The B., A. & P. Co. are now experimenting with a system of counterweights for maintaining uniform tension in contact wires regardless of temperature changes and they promise to prove entirely satisfactory.

Though as yet only a portion of the entire equipment is in service, those concerned feel justified in believing that the performance in general of the electrical equipment, including locomotives, substations, and overhead, is nothing less than remarkable, in view of the fact that practically every detail is all new special design and that the operation of the equipment has been in the hands of individuals who did not have the advantage of previous training to fit them for the work, and they feel assured that when the entire service is taken over the results will be equally as satisfactory.



Proceedings of the One Hundred and Fifth Meeting,  
Butte, Montana, August, 1913.

COMMITTEES.

*Precious and Base Metals.*

|                                                                               |                                       |                      |
|-------------------------------------------------------------------------------|---------------------------------------|----------------------|
| Charles W. Goodale, <i>Chairman.</i>                                          | L. D. Ricketts, <i>Vice-Chairman.</i> |                      |
| Darsie C. Bard, <i>Secretary, Montana State School of Mines, Butte, Mont.</i> |                                       |                      |
| Donald S. Austin,                                                             | Thomas J. Grier,                      | Willet G. Miller,    |
| David W. Brunton,                                                             | Hennen Jennings,                      | Albert F. Schneider, |
| Theodore B. Comstock,                                                         | Edmund B. Kirby,                      | George C. Stone,     |
| Wiley A. Easton,                                                              | Charles W. Merrill,                   | Benjamin B. Thayer.  |
| Samuel S. Fowler.                                                             |                                       |                      |

LOCAL COMMITTEES.

BUTTE.

|                                                            |             |                  |
|------------------------------------------------------------|-------------|------------------|
| <i>General Committee.</i> —C. W. Goodale, <i>Chairman.</i> |             |                  |
| P. Mathewson,                                              | J. D. Pope, | Geo. A. Packard, |
|                                                            | D. C. Bard. |                  |

*Program.*—John Gillie, *Chairman.*

|             |              |
|-------------|--------------|
| Oscar Rohn, | J. L. Bruce. |
|-------------|--------------|

*Transportation and Accommodation.*—H. A. Gallwey, *Chairman.*

|               |                 |                |
|---------------|-----------------|----------------|
| P. Mathewson, | C. H. Bowman,   | B. H. Dunshee, |
|               | F. A. Linforth. |                |

*Entertainment.*—G. E. Moulthrop, *Chairman.*

|              |                |
|--------------|----------------|
| R. H. Sales, | H. A. Gallwey. |
|--------------|----------------|

*Ladies' Entertainment.*—Oscar Rohn, *Chairman.*

|            |                    |                |
|------------|--------------------|----------------|
| C. Febles, | R. A. MacArthur,   | B. H. Dunshee, |
|            | Samuel Barker, Jr. |                |

*Press.*—G. A. Packard, *Chairman.*

|            |                 |                  |
|------------|-----------------|------------------|
| x. Leggat, | W. C. Siderfin, | Theodore Simons. |
|------------|-----------------|------------------|

GREAT FALLS.

*General Committee.*—A. E. Wheeler, *Chairman.*

|                  |              |
|------------------|--------------|
| J. H. Klepinger, | W. T. Burns. |
|------------------|--------------|

*Program and Entertainment.*—J. H. Klepinger, *Chairman.*

|            |                  |                 |
|------------|------------------|-----------------|
| W. Krejci, | Arthur Crowfoot, | E. S. Bardwell, |
|            | J. A. Church.    |                 |

*Press.*

|               |               |
|---------------|---------------|
| Robert Ammon, | C. R. Kuzell. |
|---------------|---------------|

*Transportation.*—W. T. Burns, *Chairman.*

|                |               |                 |
|----------------|---------------|-----------------|
| Frank Scotten, | F. R. Corwin, | E. E. Brownson. |
|----------------|---------------|-----------------|

ANACONDA.

*General Committee.*—E. P. Mathewson, *Chairman.*

|            |             |               |
|------------|-------------|---------------|
| Ed Laist,  | E. M. Dunn, | C. D. Demond, |
| V. Bender, | H. S. Ware, | H. L. Welsh.  |

The opening session was held on Saturday evening, Aug. 16, 1913, at the Court House, Great Falls, Mont., and was called to order by Charles W. Goodale who, after a short address of welcome, introduced President Charles F. Rand, who responded to the address of Mr. Goodale and presided thereafter at the meeting.

The following papers were then presented in oral abstract by their authors, or authors' representatives:

Hydro-Electric Development in Montana, by Max Hebgén. Discussed by Frank Scotten, Joseph W. Richards, and another.

Notes on the Great Falls Electrolytic Plant, by W. T. Burns. Discussed by Joseph W. Richards.

The Great Falls Flue System and Chimney, by C. W. Goodale and J. H. Klepinger. Discussed by Joseph W. Richards and J. H. Klepinger.

The Determination of Arsenic and Antimony in Converter and Electrolytic Copper, by E. E. Brownson.

Great Falls Converter Practice, by A. E. Wheeler and M. W. Krejci. Discussed by Bradley Stoughton, Joseph W. Richards, S. LeFevre, and M. W. Krejci.

The Smelting of Copper Ores in the Electric Furnace, by D. A. Lyon and R. M. Keeney. Discussed by M. W. Krejci, C. D. Woodward, Joseph W. Richards, Bradley Stoughton, and D. A. Lyon.

The following papers were read by title:

Preparation of Ore Containing Zinc for the Recovery of Other Metals such as Silver, Gold, Copper, and Lead by the Elimination and Subsequent Recovery of the Zinc as a Chemically Pure Zinc Product, by S. E. Bretherton.

Some Recent American Progress in the Assay of Copper-Bullion, by Edward Keller.

The second session was held at the Auditorium in Butte, Mont., on Monday, Aug. 18, 1913, at 9.30 a. m. After an address of welcome by the Hon. Cornelius F. Kelley, which was responded to by President Charles F. Rand, the following papers were presented in oral abstract by their authors, or authors' representatives:

The Ore Deposits at Butte, Mont., by Reno H. Sales. Discussed by L. C. Graton, W. C. Ralston, Joseph W. Richards and R. H. Sales.

Mineral Associations at Butte, by D. C. Bard and M. H. Gidel.

Timbering in the Butte Mines, by B. H. Dunshee.

Shaft-Sinking Methods at Butte, by Norman P. Braly.

The Use of Electricity in Mining in the Butte District, by John Gillie.

The last three papers were discussed jointly by G. E. Moulthrop, A. A. Packard, and Norman P. Braly.

The following papers were read by title:

The Kennedy Mining District, Nevada, by Paul Klopstock.

Notes on the Occurrence of Some of the Rarer Metals in Blister Copper, by Anton Eilers.

Biographical Notice of John Fritz, by H. S. Drinker and R. W. Raymond.

Assay for Gold and Silver by the Iron-Nail Method, by E. J. Hall and C. W. Drury.

An Assay for Corundum by Mechanical Analysis, by W. Spencer Hutchinson.

The third session was held at the Auditorium in Butte, on Monday evening, Aug. 18, 1913, at 8 p. m. Mr. Charles W. Goodale presided. The following papers were presented in oral abstract by their authors, or authors' representatives:

Development of the Basic-Lined Converter for Copper Mattes, by J. P. Mathewson. Discussed by Joseph W. Richards and C. D. Raymond.

Roasting and Leaching Tailings at Anaconda, Mont., by Frederick Laist. Discussed by J. C. Dick and F. Laist.

The Use of the Microscope in Mining Engineering, by F. W. Apgar. Discussed by L. C. Graton.

The Evolution of the Round Table for the Treatment of Metalliferous Slimes, by Theodore Simons.

The following papers were read by title:

Mining Cost Accounts of the Anaconda Copper Mining Co., by L. T. Van Ella.

The Development of Blast-Furnace Construction at the Boston & Montana Smelter, by John A. Church, Jr.

The Gold Placers of Antioquia, Republic of Colombia, by M. H. de Hora.

The Tooele Plant of the International Smelting & Refining Co., by J. H. Thompson and L. T. Sicka.

Hardinge Mills vs. Chilean Mills, by Robert Franke.

The New International Diamond Carat of 200 Milligrams, by George F. Kunz.

The Laws of Jointing, by Blamey Stevens.

Method of Testing Draeger Oxygen Helmets at the Copper Queen Mine, by Charles A. Mitke.

The fourth session was held in the Margaret Theatre, at Anaconda, Mont., on Tuesday, Aug. 19, 1913, at 2.30 p. m. An address of welcome by E. P. Mathewson was responded to on behalf of the Institute by Prof. Joseph W. Richards. Mr. Mathewson presided at the meeting.

The following papers were presented in oral abstract by their authors, or authors' representatives :

Concentration of Slimes at Anaconda, Mont., by Ralph Hayden.

The Great Falls System of Concentration, by Albert E. Wiggin.

The Anaconda Classifier, by Robert Ammon.

Application of Hindered Settling to Hydraulic Classifiers, by E. S. Bardwell.

Determination of Gases in Smelter Flues; and Notes on the Determination of Dust Losses at the Washoe Reduction Works, Anaconda, Mont., by Edgar M. Dunn.

Arsenic Trioxide from Flue Dust, by James O. Elton.

Ore-Dressing Improvements, by Robert H. Richards.

Topographic Maps for the Mining Engineer, by E. G. Woodruff. Discussed by C. W. Goodale, F. A. Linforth, E. P. Mathewson, E. W. Parker, Van. H. Manning, and John Gillie.

The fifth session was held at the Auditorium, in Butte, Mont., on Wednesday, Aug. 20, 1913, at 9.30 a.m. Prof. Joseph W. Richards presided. The following papers were presented by their authors, or authors' representatives :

The Southern Cross Mine, Georgetown, Mont., by Paul Billingsley.

The Reducibility of Metallic Oxides as Affected by Heat Treatment, by W. McA. Johnson.

Rock-Drilling Economics, by William L. Saunders.

A Note on the Occurrence and Manufacture of Refractories in Montana, by W. H. Gunniss. Discussed by Joseph W. Richards and E. P. Mathewson.

Applied Geology in the Butte Mines, by F. A. Linforth. Discussed by B. H. Dunshee.

The following papers were presented by title :

Thermal Effect of Blast-Furnace Jackets, by Robert P. Roberts.

The Discovery and Opening of a New Phosphate Field in the United States, by C. Colcock Jones.

The sixth session was held at the Auditorium, in Butte, Mont., on Wednesday, Aug. 20, 1913, at 8.30 p.m. First Vice-President Benjamin B. Thayer presided. The following papers were presented in oral abstract by their authors, or authors' representatives :

The Precipitation of Copper from the Mine Waters of the Butte district, by John C. Febles. Discussed by Joseph W. Richards.

Notes on the Electrolytic Refining of Copper Precipitate Anodes, by W. T. Burns.

The Compressed Air System of the Anaconda Copper Mining Co., Butte, Mont., by Bruno V. Nordberg.

Increasing the Efficiency of MacDougall Roasters at the Great Falls Smelter of the Anaconda Copper Mining Co., by F. R. Corwin and S. Rodgers.

The Tin Situation in Bolivia, by Howland Bancroft.

Notes on the Metallography of Refined Copper, by E. S. Bardwell.

The Coal Fields of Montana, by Eugene Stebinger.

The following papers were presented by title :

The Electrification of the Butte, Anaconda & Pacific Railway, by J. E. Wade.

The Substitution of Air for Water in Diamond Drilling, by Ralph Wilcox.

The Metaline Plant of the Inland Portland Cement Co., Metaline Falls, Wash., by Milo W. Krecji.

Valuation of Coal Land, by H. M. Chance. Discussed by G. H. Ashley.

Cement Materials and the Manufacture of Portland Cement in Montana, by W. H. Andrews.

### *Excursions and Entertainments.*

The members and guests assembled at the Rainbow Hotel, Great Falls, Mont., on the morning of Saturday, Aug. 16, where registration facilities, badges, booklets, and programs were provided, and where they were met by the Local Committees.

The members were then taken by automobile to visit the hydroelectric developments at Great Falls, and Rainbow Falls, on the Missouri river, with a visit to the Giant Springs on the return trip.

In the afternoon the party was again taken by automobile to the plant of the Boston and Montana Smelter, every department of which was offered for inspection, and explained by members of the metallurgical staff.

On Sunday, Aug. 17, the members left Great Falls for Helena, where luncheon was served at the Placer Hotel through the hospitality of the Local Committee, after which a sight-seeing trip about the city was made by some of the members and guests, while others visited the lead-silver smeltery of the American Smelting & Refining Co.

At 4.20 p.m. the party left Helena, arriving in Butte in the even-

ing. The headquarters of the Institute at Butte was at the Silver Bow Club, which Club, together with the University Club and the Butte Country Club, extended its courtesies to the visiting members and guests during their stay.

On the morning of Monday, Aug. 18, the ladies of the party were entertained by the wives of the local Institute members on a sight-seeing trip about the city of Butte, with a luncheon at the Silver Bow Club, and a visit in the evening to the Butte Country Club as the guests of Mrs. Dr. F. W. McCrimmon.

In the afternoon competent guides were provided for visits by members and guests to any one of the following points of interest:

Inspection of electrically-driven air-compressor plants and air hoists at the High Ore mine.

Inspection of the underground workings and pumps at either the Original, Leonard, North Butte, or Tramway mines.

Inspection of the underground workings and of the zinc mill of the Butte & Superior Copper Co.

Inspection of the mine and of the copper-leaching plants of the Bullwhacker Copper Co., and of the Butte & Duluth Mining Co.

General surface trip of inspection of the mines and surface geology of the Butte district.

On Tuesday morning the party was taken by special train to the Washoe Smelter, at Anaconda, where they were conducted by the Local Committee on a trip of inspection through the plant. A special train then took the party to the town of Anaconda, where luncheon was served at the Montana Hotel.

In the afternoon, after the technical session, the special train carried the members and guests back to Butte.

On Tuesday evening the party assembled at the Auditorium, where some extraordinarily interesting moving pictures by Max Hebgen, illustrating the hydro-electric development of Montana, were presented. Following this special cars carried the members and guests to Columbia Gardens, where a very pleasant social evening was spent visiting the gardens, with dancing by those who cared to.

On Wednesday the ladies were carried by automobile to the Basin Reservoir as guests of the Butte Water Co. Luncheon was served, Mrs. Eugene Carroll acting as hostess, assisted by the wives of the local members. The afternoon was spent in boating on the lake, and other social recreations.

In the afternoon the men of the party made visits of inspection to the different points of technical interest in Butte, listed above.

On Thursday, Aug. 21, a special train conveyed the party to the

thern Cross mine, where an exceedingly pleasant day was spent  
ially and in visiting the mine. A very good luncheon was served  
the mine from dinner buckets.

The meeting closed with a banquet, which was given at the Silver  
w Club at 8.30 p.m. Mr. William L. Saunders acted as Toastmas-  
and the following toasts were responded to:

Cornelius F. Kelley, "Butte."

Charles F. Rand, "The A. I. M. E."

Lee Mantle, "Montana."

J. H. Durston, "The Press."

Bradley Stoughton, "Co-operation for Institute Progress."

One hundred and sixty-two members and more than 300 guests  
ended the meeting. The attendance at technical sessions varied  
m 125 to 182 each.





## Great Falls Converter Practice.

discussion of the paper of Archer E. Wheeler and Milo W. Krejci, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 1831 to 1880.

BRADLEY STOUGHTON, New York, N. Y.:—I would like to ask Mr. Krejci whether they have tried mixing coke dust with the lime in those converters and, if so, if any advantage has been found. It has been a very great advantage in the steel converters where coke dust has been mixed with the lime near the tuyeres. Of course the element that causes the corrosion at that point is oxide of iron, and coke seems to prevent the formation of the oxide of iron and so protect the tuyeres. It would be interesting to know if it had the same effect in the copper converters.

MILO W. KREJCI:—We have never tried it here. At Anaconda the tuyere section was formerly put in by mixing magnesite with tar and ramming that into the tuyere section, but they have abandoned that. Might I ask how you would apply the coke dust? How get it into the tuyere section? How hold it there?

BRADLEY STOUGHTON:—The coke dust is mixed with silica and clay and then rammed in and burned. I suppose in your converters it could be mixed with the magnetite or magnesite and then agglomerated with the material in place.

MILO W. KREJCI:—We never tried it here.

PROF. JOSEPH W. RICHARDS, South Bethlehem, Pa.:—I would like to ask how thick this deposit of magnetite is on the lining. How thick a layer would be practical?

MILO W. KREJCI:—About 2 in. would be sufficient.

SOLOMON LE FEVRE, Mineville, N. Y.:—I was interested to hear of the use of magnetite in connection with the copper smelter. I am interested in the mining of magnetite, but was not aware that it had been used at all by the copper metallurgists.

Magnetite in lump form is used largely for bottoms of open-hearth steel furnaces. The lumps are filled in with a mortar of hematite ore. The chief advantage of the Mineville, N. Y., lump ore is that it glazes the hearth when the heat strikes it, instead of decrepitating as some ores will. I see no reason why it should not be used for copper reverberatory furnaces.

Perhaps in the converters, if after the brick were heated the magnetite could be blown in with something like the "cement gun" it would immediately stick fast and form the glaze of magnetite sought for over the brick.

MILO W. KREJCI:—We might say to Mr. Le Fevre that we had discussed the advisability of trying to get some combination of this magnetite in the reverberatory, but we haven't seen our way clear to get it in there, to have it stick.

HERBERT HAAS, San Francisco, Cal. (communication to the Secretary\*): An authoritative historical review of the development of a process is not only of great interest, but also of great value, as it preserves for future workers a record of what has previously been done. A detailed history of metallurgical processes, chronicling failures as well as successes, is particularly valuable, and Messrs. Wheeler and Krejci's paper on Great Falls Converter Practice, past and present, is a valuable contribution to the literature of the metallurgy of copper. The great value of authentic historical records of the development of important industries, chiefly the metallurgical and mechanical industries, is beginning to be realized in an increasing measure by engineers, and the Institute would confer great benefit upon the copper industry and the science of copper metallurgy if it would undertake, with the co-operation of our eminent copper metallurgists and specialists, the publication of a standard work on the history of copper, that would rank with L. Becks's *Geschichte des Eisens* (History of Iron), or Conrad Matschloss's *Die Entwicklung der Dampfmaschine* (The Development of the Steam Engine) and his *Beiträge zur Geschichte der Technik und Industrie* (Contributions to the History of Technology and Industry).<sup>1</sup>

Much of our information on copper is scattered through many publications, and a great portion thereof deals more with analytical and chemical data than with the evolution in the mechanical design and construction of apparatus in use at different times. Papers that record and give due weight to the mechanical development in the metallurgy of copper are of particular value. The recent example set by Montana engineers in contributing so many excellent papers to the *Transactions* should be emulated by other workers in that field of metallurgy.

This discussion relates only to the latest development of Great Falls

\* Received Sept. 9, 1913.

<sup>1</sup> Four volumes of the latter have appeared to date; Julius Springer, Berlin.

verter practice, and I shall confine the same at present to rate of operation, *i. e.*, speed of converting: number and size of tuyeres; efficiency of air; and air volume. In December, 1912, and January, 1913, and again in May, I conducted a series of experiments with a model of a converter, Figs. 1 and 2, to study the effect of size, position, arrangement, and number of tuyeres on the circulation of the converter bath (in my experiments, water, brine, and mercury were used), and evolved a new converter construction. This work and the considerations in view were embodied in a paper, *A Proposed New Form of Converter and Modification in Bessemerizing Copper*

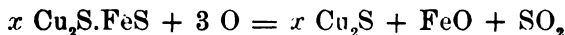


FIG. 1.—EXPERIMENTAL GLASS MODEL OF CONVERTER.

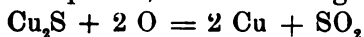
tures. It was my intention to have this paper ready for the Butte Convention, but as I have not until the present date been able to complete it, owing to pressure of other work, I trust that certain portions of proof bearing upon this discussion may here be quoted.

*Rate of Oxidation, or Speed of Converting.*

This is primarily dependent on the speed with which oxygen (air) is pumped into the converter. During the first period, when blowing the matte, we have the reaction:



and during the second period, when blowing on "white metal":



For every pound of oxygen forced into the converter there will be oxidized, according to this formula, 1.17 lb. of Fe and 0.67 lb. of S,

with the ratio of  $\frac{1.17 \text{ Fe}}{0.67 \text{ S}} = 1.75$ , during the first stage of the process, and one lb. of S during the second stage. In actual practice the ratio  $\frac{\text{Fe}}{\text{S}}$  is more nearly 2; *i. e.*, twice as much iron as sulphur (by weight) is oxidized. This is due to the fact that nearly all mattes do



FIG. 2.—SEPARATE PARTS OF MODEL.

not conform to the ideal composition  $x \text{ FeS} \cdot \text{Cu}_2\text{S}$ , in which all the copper and iron is combined with sulphur (as  $\text{Cu}_2\text{S}$  and  $\text{FeS}$ ), but have metallic copper dissolved in the  $\text{FeS}$ ; the greater the amount of  $\text{FeS}$ , the greater is the amount of metallic copper that can be so held in solution.

As converting progresses, the amount of  $\text{FeS}$  diminishes, and with it the amount of metallic copper that is held in solution. That is, the relative amount of copper combined with sulphur increases and the amount of metallic copper decreases as the  $\text{FeS}$  diminishes, until

etically all FeS is eliminated, and blowing on "white metal" ins. This is equivalent to a decrease in the rate of elimination of sulphur, and an increase in the rate of elimination of the iron. A tion of iron already oxidized is also introduced with the siliceous t, which is not properly chargeable to iron elimination by air dation. By computing the rate of oxidation on the basis of the nula  $\text{FeS} + \text{Z O}$ , the converting speed would really be somewhat ver than in actual practice, but the above figures are sufficiently arate to determine converter capacity.

Thus, by forcing 200 kg. of oxygen per minute into the converter, kg. of Fe per minute would be oxidized to 300 kg. of FeO (assum- that no  $\text{Fe}_2\text{O}_3$  is formed), and 133 kg. of S per minute to 266 kg.  $\text{SO}_2$ . Two hundred kg. of oxygen corresponds to 870 kg. of air, al to 673 cu. m. (at standard conditions of temperature and pres- e), or 24,000 cu. ft., of air per minute, which corresponds closely he air volume used in the latest 20-ft. Great Falls converter. The per distribution or diffusion of so large a volume of air through the verter charge is not only necessary to secure the required speed of ction, but to blow on shallow charges with low air pressure, to pre- t the throwing out of the converter charge and to avoid mechanical es (shot copper and matte), accretions on and fouling of the con- ter mouth, and undue localization of oxidation, with increased r on the lining in the tuyere zone. It is to this subject pertaining pper-converter construction that I have given my attention since introduction of the large Pierce-Smith basic-lined converters, and one more recently put into operation at Great Falls.

My own experiments with the glass model converter confirmed at Messrs. Wheeler and Krejci described with reference to the cir- ation in their small experimental tank with glass bottom. That air blast would not penetrate the charge appreciably in a forward (horizontal) direction before it rises is to be expected on purely sical grounds, as the mass ( $m = \frac{W}{g}$ ) of air compared with that of er is very small, and still smaller as compared with that of matte, hat the force stored in the air is soon spent, owing to the resist- e offered by the matte. The vertical component of the reacting es, due to the low specific gravity of the air, which has only about  $\frac{1}{10}$  of the weight of an equal volume of matte when heated to the perature of the converter contents, is infinitely larger than the izontal component, so that the resultant will be practically vertical; , the air will rise almost immediately.<sup>2</sup> It will rise more quickly

<sup>2</sup> called attention to this action of the air in a side-blown converter in a previous article, Vortex Copper Converter, *Engineering and Mining Journal*, vol. lxxxix., No. 19, p. (May 7, 1910).

through matte than through water, provided viscosity is not an impeding force. Such an impedance is offered by the converter slag, which is viscous compared with slags made in furnace operations. How the converter slag may affect the speed of converting will be shown below.

"To set up a circulation in a direction opposite to that described as had been thought probable" by Messrs. Wheeler and Krejci, is hardly feasible, for other reasons than that already given above, which reasons will also explain why the circulation in a side-blown copper converter is precisely of the nature observed by Messrs. Wheeler and Krejci in their experiments. In a converter this circulation is greatly intensified.

One of the considerations that led me to design a bottom-blown converter was the apparent localization of the oxidation in the present type of side-blown converter. This is especially noticeable in the Great Falls converter, where the tuyeres are confined to a relatively small portion of the inside converter perimeter, and the tuyere orifices are from 8 to 15 ft. removed from the opposite side of the converter. In the large Pierce-Smith converters this distance, as a rule, is 10 ft. Here the localization of the oxidation is not quite so pronounced, as the tuyeres are spaced over the entire length of the cylinder (from 20 to 30 ft. inside) and a much smaller air volume is delivered. Notwithstanding this condition of concentrating the blowing to one side of these converters, new matte is constantly brought into contact with the air. Comparing the density of air with that of water, matte, "white metal," and blister copper, we find that at ordinary temperatures, say  $15^{\circ}\text{C.}$ , 1 cu. m. of water is 800 times heavier than 1 cu. m. of air, that matte is 3,600 times heavier, "white metal" 4,400 times heavier, and blister copper 6,800 times heavier than an equal volume of air. This air, when pressed into the converter, is heated to the temperature of the converter contents (from  $1,150^{\circ}$  to  $1,200^{\circ}\text{C.}$ ), as the result of which the gases expand to about five times the original air volume. Thus the gas becomes correspondingly lighter, the relative weights of equal volumes of matte and gas being about as 18,000 to 1. This large volume of gas is principally confined to the tuyere zone, and the matte near the tuyere zone is rendered less dense thereby. The matte in the other part of the converter, which is not diffused by gas, retains its normal density, and exerts, therefore, a greater hydrostatic pressure. As this is equal in every direction, at any given height, a differential in pressure exists between this matte of normal density and the "wall" of gas-diffused matte of lower density. This condition will set up a flow in

direction of the tuyere-zone which will bring into contact with air a constant fresh supply of matte. At the tuyere level, where hydrostatic pressure is greater than at points higher up, this flow, circulation, will be more rapid. The large volume of gas will rise with it and bring to the surface of the matte bath a certain amount of matte and create a violent wave motion in a direction away from the tuyere side. This localization of the oxidation and circulation at the tuyere zone causes increased wear on that portion of the converter lining. In Fig. 3 the circulatory action above described is illustrated.

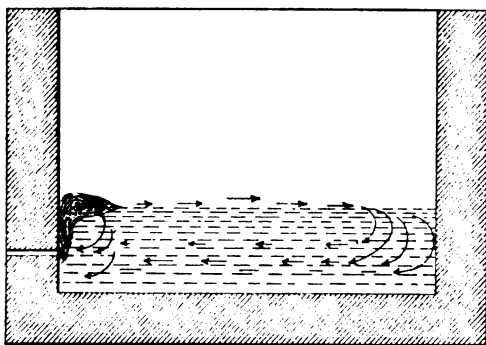


FIG. 3.—CIRCULATION OF THE BATH IN A SIDE-BLOWN CONVERTER.

Arguing that the rate of conversion could be increased, and at the same time the intense localization of the oxidation in so small an area of the large converters used at present greatly reduced, I designed a bottom-blown converter, the salient points of which are shown in Figs. 4, 5, and 6.

Referring to Fig. 4, it will be at once noticeable that the tuyeres are not distributed over the entire converter bottom, but are confined to a concentric area, in size about one-quarter of the total area of the bottom. This confines the oxidation and the ascending gases to a central column of the converter bath. The gases here have the same effect of materially decreasing the density of the matte as has been explained above for the side-blown converter, but with this marked difference: The outside "ring" of matte inclosing the central "tuyereyser," having a greater density and therefore greater hydrostatic pressure, is continually flowing toward the tuyere bottom, and descends with a large volume of gas, overflowing at the surface and spreading toward the periphery.

In Fig. 5 this tuyere bottom is elevated, the brickwork being supported by a hollow, cast-steel truncated cone, which serves as a wind

box. This elevated tuyere bottom forms an annular sump, in which can be stored a considerable tonnage of matte. With this raised tuyere bottom, it is possible to blow on a shallow bath of matte and yet have a large volume of matte stored in the converter. This matte acts as a heat accumulator, and will be particularly useful when concentrates are to be smelted in the converter by blowing them into the matte through the tuyeres. This feature, to which my converter is

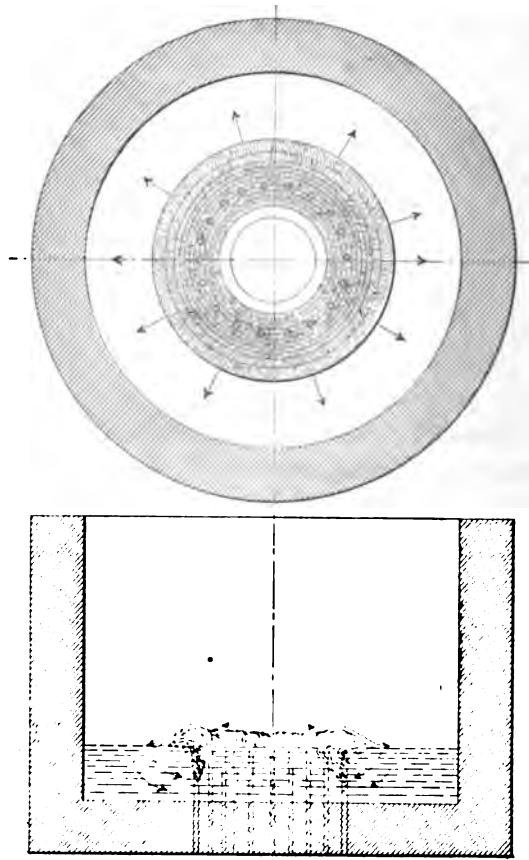


FIG. 4.—PLAN AND SECTION SHOWING CIRCULATION OF THE BATH IN HAAS BOTTOM-BLOWN CONVERTER.

especially applicable, I shall discuss at greater length in my paper. Suffice it to say here, that with the wind box closed, and in the absence of tuyere valves and tuyere punching, there could be no objection to this practice on the ground of mechanical losses through the tuyere valves when the tuyeres are being punched.

My converter is also provided with a large slag mouth, a short dis-



nce above the slag line. Instead of tilting the converter completely skim the slag, or blowing for too long a period on matte and letting the slag accumulate, this converter would be tilted at frequent intervals to pour off the slag. To accomplish this, the converter will have to be tilted only a few degrees. The removal of the slag at frequent intervals appears especially desirable, as it has been observed that the rate of oxidation falls off if the slag is left to accumulate and increases with the bath skimmed clean of slag.<sup>3</sup> This may be due to the fact that the  $\text{SO}_2$  gas may be kept included in the matte, as it cannot pass so freely through the viscous slag, and thus vitiates the oxidizing power of the air.

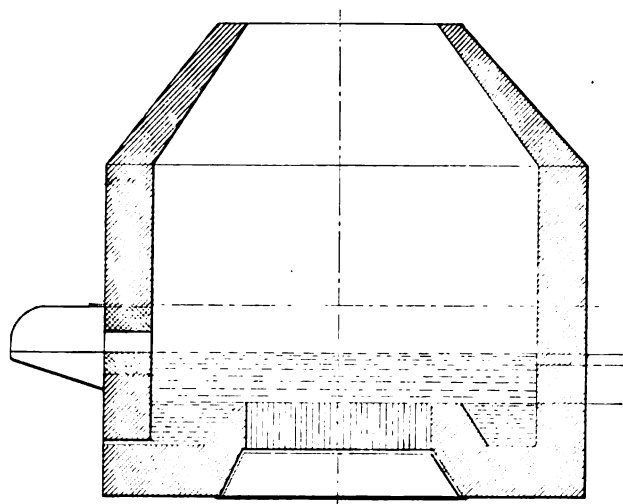
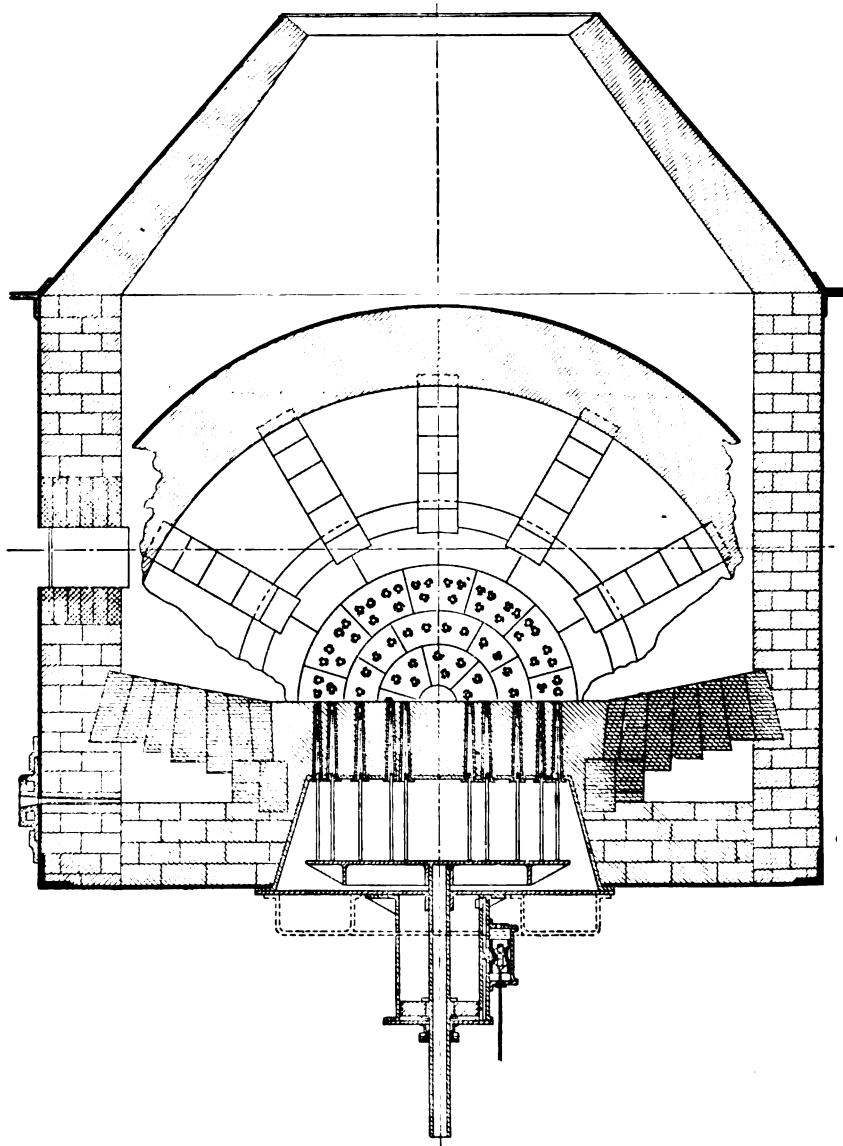


FIG. 5.—ELEVATED TUYERE BOTTOM FOR BOTTOM-BLOWN CONVERTER.

The static column is also kept low by a frequent removal of the slag. The converter would be worked very much as converters are worked at present. Frequent charges of matte are given, until there is a considerable accumulation of white metal. The peculiar feature, when working with the elevated tuyere block, is the slight increase in the height of the matte column above the tuyere block, as with the elimination of a portion of the sulphur and of the iron the matte shrinks in volume. When blowing on "white metal" begins, the height of the column above the tuyeres becomes constantly less, with a constant reduction in air pressure required, notwithstanding the fact that the density increases at the same time. This is due to a certain relationship between the area and volume capacity of the



Height, 15 ft. ; helmet, 7 ft. Diameter, shell, 20 ft. ; inside, 16 ft. 90 tuyeres, 1.5 in. in diameter. Storage capacity of sump, approximately 264 cu. ft., or about 70 tons of copper.

FIG. 6.—HAAS CONTINUOUS CONVERTER WITH VERTICAL TUYERES AND AUTOMATIC TUYERE PUNCHER.

converter, and the height of the tuyere block above the converter bottom proper.

The method of mounting and operating the converter is not different from that now in use. The shell is connected with large riding rings resting on rollers, or riding wheels. To one of the riding rings is bolted a gear ring, which is engaged by a pinion that is operated by a further reduction of gears from a direct-current motor. The drive can also be made hydraulic. The converter has enough of a belly to hold the converter contents when turned down in the direction opposite to that of the slag mouth, so that it has all of the advantages of the converters now in use. To secure the best possible distribution of the air through the matte, and to attack as large a matte surface as possible, I have provided my bottom-blown converter with a large number of tuyeres of small cross-sectional area. This has also been done to avoid the formation of "noses," which my investigations lead me to believe are wholly due to the large volume of air introduced per tuyere in the present type of side-blown converter. By establishing a proper ratio between the weight of air introduced through each tuyere per minute and the weight and size of a "column" of matte immediately above and surrounding each tuyere orifice, spilling should be prevented. The weight of air introduced per minute through each tuyere is reduced to a point at which enough heat can be transmitted from the matte to the air to heat the latter and still leave the matte surrounding the rising air currents at the tuyere orifice in a molten condition. The matte flowing toward the tuyere bottom would make up any deficiency in heat. In the side-blown converter this new matte comes from one side only, the other side being bounded by the converter wall. By subdividing the air currents the air surface exposed to the matte will be greatly increased, and at the very point when it enters the matte, and the air will thus be more readily heated. It will also permit of working with a shallower charge, as there will be less concentration of air at a few points, with the possibility of a portion of this concentrated air volume escaping without all of its oxygen having been utilized, unless it is made to travel through a deeper matte bath to prolong its contact with the matte. I shall not use space at present to set forth thermo-chemical calculations incorporated in my paper, which confirm my view that a top converter can be bottom blown without having to resort to the use of any punching of tuyeres.

Messrs. Wheeler and Krejci are quite correct in saying that "with proper distribution of the air through the charge the speed of the reactions in the converter is undoubtedly beyond any practical rate of

supplying the air." While it is only within recent years, beginning with the introduction of Pierce-Smith basic-lined converters, that the volume of air blown into copper converters per minute was materially increased, from 800 to 1,000 kg. of air per minute (22,000 to 27,400 cu. ft. per minute) has been the rate of air supply to 20- and 25-ton Thomas (steel) converters for a number of years. This is a size no longer uncommon in large steel works which use the Thomas process. These converters are by no means as large as the 20-ft. Great Falls converter, but they convert considerably faster, the elapsed time being greatly reduced. While the 20-ft. Great Falls converter has about three times greater air supply than is usual with the Pierce-Smith and the smaller 12-ft. size Great Falls converters now being installed in various works, I look for a greatly increased air supply to copper converters, as the use of magnesite linings will make this increased converting speed possible. So-called "needle bottoms," in contradistinction to "tuyere bottoms,"<sup>4</sup> have been commonly used for a number of years in Thomas converters with great success, and they are not only considered a great advance over the old style tuyere bottoms, but one of the principal recent advances in Thomas converter practice.<sup>5</sup> These needle bottoms have a large number of small tuyeres, from 250 to 300 of them in 20- to 25-ton converters, their diameter being from 15 to 18 mm. Thus the amount of air introduced per tuyere per minute varies from 3 to 3.5 kg., whereas in the Pierce-Smith converter it is from 6 to 12 kg., and in the latest Class V 20-ft. Great Falls converter about 14 kg., with 62 1.75-in. tuyeres, and about 34 kg. with the number of tuyeres reduced to 26 (2.25 in.). From the very start of copper converter operations the weight of air per minute per tuyere has been larger than in steel converting, and as long as an acid lining was used, that corroded rapidly, a limited number of tuyeres was desirable for various reasons. The formation of noses and clogging of tuyeres was pronounced, as corrosion or "slagging" of the lining was most intense in the tuyere zone, due to the circulation set up as described above. This made constant punching necessary, and for reasons of construction and attendance a limited number of tuyeres was desirable. In basic-lined converters

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<sup>4</sup> The tuyere bottoms usually have, not a few large tuyeres, but a number of tapered tuyere bricks, each containing from 10 to 20 small tuyeres, from 0.25 to 0.5 in. in diameter. If a brick is damaged, another one may be inserted in its place. This has the same effect as a few large tuyeres would have of concentrating the volume of air in a few places. In the "needle bottoms" the tuyeres are evenly distributed over the entire bottom. See F. W. Harbord, *The Metallurgy of Steel*, 2d ed., pp. 9 *et seq.*, 60 *et seq.*

<sup>5</sup> 30 Jahre Thomas-Verfahren in Deutschland, *Stahl und Eisen*, vol. xxix, No. 38, p. 1486 *et seq.* (Sept. 22, 1909).

slagging does not occur in the tuyere zone, but above it, so that the air blows only on matte, and if the amount of air passing through each tuyere per minute be limited sufficiently I can see no reason why punching should be any more necessary than it is in steel converting.

To heat 1 kg. of air from  $0^{\circ}$  C. to  $1,150^{\circ}$  C. requires  $0.303 + 0.000027 t \times 1,150^{\circ}$  C. = (in round numbers) 300 kg-cal.<sup>6</sup>  
 $\frac{1.293}{1.293}$

It will therefore be seen that in the Great Falls converter, with 62 1.75-in. tuyeres, and an air supply of 14 kg. per minute per tuyere, 4,200 kg-cal. have to be supplied every minute by the matte for each tuyere (70 cal. per second), and with 26 2.5-in. tuyeres this is increased to 10,200 cal. per minute per tuyere (170 cal. per second). This is undoubtedly far in excess of the rate at which the matte can transmit the heat before it will chill around the tuyere orifice, especially so in view of the close spacing of large tuyeres in side-blown converters and the concentration of air volume.

In the modern Thomas converter, due to the higher temperature, about 400 cal. are required to heat 1 kg. of air, so that here only from 1,200 to 1,400 kg-cal. per minute per tuyere have to be supplied. In my converter I propose to keep it between 800 and 1,000 kg-cal. per tuyere per minute.

Taking as an example my converter of 20 ft. outside diameter and 16 ft. inside of lining, in which I restrict the tuyeres to a circular area 8 ft. in diameter in the center of the converter, thus forming a tuyere bottom 50 sq. ft. in area, which is surrounded by the balance of the converter bottom, of some 150 sq. ft. in area, and using 300 18-mm. tuyeres, I would have a total tuyere area of some 120 sq. in., or  $\frac{144 \times 50}{120} = 60$  sq. in. of matte surface per 1 sq. in. of tuyere area.

It is difficult to figure the exact relation between tuyere distribution and the matte surface belonging to it in a side-blown vertical converter, as all tuyeres are arranged in a line lying in the same plane through the vertical wall of the converter.

Allowing 240 in. as the length of the arc in which the tuyeres of the Great Falls converter are placed, and allowing the same distance above and below each tuyere as the distance between centers of tuy-

<sup>6</sup> As nitrogen forms the largest portion of the converter gases, and the mean specific heat of  $\text{SO}_2$  is greater than that of air, the fact that part of the oxygen of the air combines with  $\text{FeO}$  may be neglected, as this way of figuring agrees within 5 per cent. with the amount of heat carried off by the waste gases. It is reasonable to suppose that the air is heated to the temperature of the matte before oxidation is rapid. In the above calculation the loss in heat of the air on expanding when leaving the tuyere orifice was neglected.

eres, we would have an approximate surface of  $8 \times 240 = \frac{1,920}{157} =$

12.2 sq. in. of matte surface per 1 sq. in. of tuyere area, and  $\frac{1,920}{106} =$

18.2 sq. in. of matte surface per 1 sq. in. of tuyere area, with the 62 and 26 tuyeres respectively.

With this subdivision of the air currents, the air surface exposed to the matte when the air leaves the tuyeres is also greatly increased. In the Great Falls converter this is only 184 sq. in. for 1 in. length of the projected air current (product of 1 in. length  $\times$  periphery of tuyere opening), whereas it is 670 sq. in. in my converter, or 3.64 times as large. This will influence very favorably the speed of reactions.

#### LARGE TUYERES VERSUS SMALL TUYERES IN CONVERTERS.

“Another point of superiority of a few large tuyeres, within the limits of working, over many small ones, is in the decreased resistance to the air, and consequently a lower necessary pressure.”

I agree with the first part of this statement by Messrs. Wheeler and Krejci, and if we were dealing simply with a case of selecting the proper size of pipes to accommodate a certain flow of air large pipes would be dictated on the ground of power economy. But it does not follow that if a large number of small tuyeres were used in a converter a higher working pressure would be necessary, which is implied in the closing part of the above-quoted statement. With proper modifications in design, on account of the altered conditions introduced with the use of a large number of tuyeres, the *total* frictional losses in my type of converter need not be greater than those in the side-blown type, which uses a few large tuyeres.

The principal power loss, or drop in pressure, is at the tuyere orifices, and not in the tuyere pipes themselves. This power loss is chiefly due to the contraction of the tuyere orifices by frozen matte adhering to them, which makes the orifices not only smaller in area, but very rough, thereby greatly increasing the velocity and frictional resistance. This increase in the velocity head and friction head brings about a drop in pressure, or loss in effective power; that is, the power used in compressing the air is mainly spent in imparting this increased velocity to the air, causing a drop in pressure and a decrease in the air volume delivered. After the air pressure at the tuyere orifices has been lowered through loss of power represented by the velocity head and friction head, there must still be sufficient

excess pressure left to overcome the various resistances offered by the matte, which, in addition to the actual static head, are due to surface tension, viscosity of the liquid, etc. As I have already stated, I believe that it is the large volume of air flowing through each tuyere that is responsible for chilling and the consequent formation of noses; of this chilling and its effect in increasing the power requirements there is no doubt, as we have ample illustration of it in operating basic-lined copper converters, where the tuyeres must be punched frequently to keep them open and to prevent the air pressure from rising rapidly. As the charge of the basic-lined converter must be kept at a relatively low temperature (1,150° C.) to prevent excessive corrosion of lining, this tendency of the air blast to form noses is increased. As explained before, the character and form of an orifice through which air flows influence frictional losses tremendously; Weisbach's, and later Zeuner's, exhaustive investigations on the flow of water and gases (air, steam, etc.) through orifices have shown how much the character and shape of an orifice influence the contraction of the vein or flowing stream and friction, and determined a large number of empirical coefficients, to make allowance for varying conditions. In the case of the converter we are dealing with especially complex conditions, which are constantly changing, so that figuring the theoretical and effective velocities and weights of the air delivered through converter tuyeres by Zeuner's formula<sup>7</sup> is of little practical value. If it were a case of determining the amount of flow of air through a nozzle from an air receiver or air main, this could be done quite accurately.

That frictional losses in converting are quite large is evident from the fact that the ratio between static matte pressure and total air pressure used varies from 0.2 to 0.4; i. e., an air pressure from 5 to 2.5 times greater than the pressure due to static head is required.

Part of this excess pressure is, of course, requisite for safety to avoid filling of tuyeres. I figured the drop in pressure due to friction in the tuyere pipes of the Great Falls converter and bottom-blown converter of my type, using Lorenz's formula.<sup>8</sup>

$$\frac{\Delta P}{P_m} = a \frac{Lv^2}{dT}$$

<sup>7</sup> For a full explanation of the derivation of this formula, which is a subject beyond the compass of this communication, consult the works of Dr. Gustav Zeuner: *Technische Thermodynamik*, vol. ii., pp. 137 to 186, and vol. i., pp. 212 to 232. A. von Ihering: *Die Gebläse*, 2d ed., Part II, pp. 708 to 744. *Hütte*, 19th ed., vol. i., p. 326 et seq.

<sup>8</sup> *Hütte*, 19th ed., vol. i., p. 335 et seq.

In which  $\Delta P$  = drop in pressure.

$P_m$  = mean pressure in pipe.

$L$  = length of pipe in meters.

$v$  = velocity of flow in meters per second.

$d$  = diameter of pipe in millimeters.

$T$  = absolute temperature =  $273 + 0^\circ \text{C}$ . [pipe.

$\alpha$  = empirical coefficient, depending on diameter of

20-ft. Great Falls Converter.

26 2.25-in. Tuyeres.

$d = 57 \text{ mm}$ .

$L = 0.8 \text{ m}$ . (length of tuyere pipe).

$v = 170 \text{ m-sec}$ .

$T = 273^\circ + 100^\circ \text{C} = 373$ .

$\alpha = 0.042$ .

20-ft. Haas Converter.

300 18-mm. Tuyeres.

$d = 18 \text{ mm}$ .

$L = 0.8 \text{ m}$ .

$v = 150 \text{ m-sec}$ .

$T = 373$ .

$\alpha = 0.050$ .

$$\frac{\Delta P}{P_m} = 0.042 \frac{170^2 \times 0.8}{57 \times 373}$$

$$0.042 \frac{23,120}{21,261}$$

$$= 0.0458 = 4.58 \text{ per cent.}$$

$$\frac{\Delta P}{P_m} = 0.05 \frac{150^2 \times 0.8}{18 \times 373}$$

$$0.05 \frac{18,000}{6,714}$$

$$= 0.1340 = 13.40 \text{ per cent.}$$

$$\Delta P = P_m \times 0.0458 = 0.0275 \text{ kg-cm.}^2 \quad \Delta P = P_m \times 0.134 = 0.0804 \text{ kg-cm.}^2$$

In both cases a working pressure of  $0.6 \text{ kg-cm.}^2$ , or  $8.53 \text{ lb. per square inch}$ , has been taken as a basis of comparison. ( $1 \text{ kg-cm.}^2$  or metric atmosphere =  $14.2234 \text{ lb. per square inch}$ .)

The formula  $h_w = f L \frac{v^2}{4d}$  gives somewhat different values. In this formula  $h_w$  is the "head" expressed in millimeters of water column required to overcome the resistance or friction offered by the pipe to the flow of air,  $f$  is an empirical coefficient of friction =  $0.003$ ,  $L$  = the length of the pipe in meters,  $v$  is the velocity of flow in meters per second, and  $d$  is the pipe diameter in meters.<sup>9</sup>

According to this formula, using the same values as above, the frictional head for the Great Falls converter (2.25-in. tuyeres) is  $305 \text{ mm. of water}$ , or  $0.0305 \text{ kg-cm.}^2$ , and for the Haas converter, with

<sup>9</sup> See A. von Ihering: *Die Gebläse*, 2d ed., part II., p. 660 et seq. (Julius Springer, Berlin).

Knipping: *Zeitschrift des Vereines deutscher Ingenieure*, vol. lvii., No. 31, p. 1218 et seq. (Aug. 2, 1913).

D. W. Taylor, U. S. N.: *Transactions of the Society of Naval Architects and Marine Engineers*, vol. xiii., p. 9 et seq. (1905).



18-mm. (0.708-in.) tuyeres, 750 mm. of water, or 0.075 kg.-cm.<sup>2</sup> With the same gauge pressure, viz., 0.6 kg.-cm.<sup>2</sup>, the percentage losses would be 5.1 and 12.5 per cent. respectively.

This formula is not strictly applicable for these conditions when as high a pressure as is customary in converting is used, but is used mainly to measure frictional resistance in heads of water in ventilating and fan systems. The Lorenz formula, based on very extensive investigations, is used to measure the drop in pressure due to friction in pipe lines conveying compressed air, and should give values sufficiently correct for our purpose.

In both of these calculations, the velocity was figured according to the formula  $V = \frac{Q}{A}$ , in which  $V$  is the velocity of flow of the air in meters per second,  $Q$  the volume of air in meters delivered per second, and  $A$  the discharge area in meters. The air volume delivered to both converters was figured at 25,000 cu. ft., or 710 cu. m., per minute, the area as 106 and 120 sq. in. respectively. In reality, this (theoretical) condition is not attained, as a smaller volume would be delivered through this area, due to contraction of the stream and friction due to rubbing and turbulence of the air. The quantity would therefore only be  $Q = \mu A V$ , in which  $\mu$  is a coefficient taking these resistances into consideration.

If this volume is to be delivered, additional pressure is needed to make up for this loss in delivery. In the case of the large tuyeres, there is an additional factor introduced, due to the contraction of the tuyere orifices themselves; i. e., a partial closing of them by frozen matte. This reduces the effective tuyere area constantly, bringing about an increase in velocity. This increased velocity can only be imparted by an expenditure of power. An increase in the velocity head  $\frac{v^2}{2g}$  means a decrease in pressure. If the blowing engine were to continue to work at the same pressure at which it worked before the orifices were contracted there would be a lessened air delivery. If the air delivery is to be kept constant, the engines can deliver it only at an increased pressure. With a further contraction of the tuyere area, the pressure limit of the engine may be reached, and, notwithstanding a high working pressure, a smaller volume of air be delivered.

As can be seen from the above formulæ, velocity influences frictional losses more than any other factor, since friction increases as the square of the velocity, and only directly as the length and inversely as the diameter of the pipe. Thus with a 25 per cent. contraction of the

tuyere area frictional losses in the tuyere pipes of the Great Falls converter would be 8.4 per cent., and with a 50 per cent. contraction, 19.2 per cent. These figures, being based on theoretical velocities and deliveries, are too low, but are near enough to illustrate how an increase in velocity affects frictional losses. Losses on account of the roughness and shape of the orifices are not included in the above figures. These figures also show that frictional losses need not be prohibitive, notwithstanding the use of a large number of tuyeres, provided such tuyeres are kept open by a decreased air flow through each tuyere and a moderate air velocity is maintained. As the life of the tuyere bottom in a copper converter will be longer than that in a steel converter, where the conditions are extremely severe with temperatures up to  $1,600^{\circ}\text{C.}$ , the tuyeres would be provided, as is done now, with smooth pipes, to keep frictional losses down.

In the foregoing I have discussed only the influence of pipe surface on the resistance to the flow of air. But in converting we should also discuss the influence of the size of tuyeres on the probability of the liquid matte "breaking through" the pneumatic column, or "piston," in the tuyere pipes and filling them. It may be stated axiomatically that the larger the diameter of the supporting air column, the greater is the danger of the matte flowing into the tuyeres, so that to prevent such filling of the tuyeres a higher air pressure is necessary with large tuyeres than with smaller ones. This very tendency of the matte to flood large tuyeres will cause the operator to carry a safe margin of excess pressure to prevent this possibility.

With large tuyeres there exists always the danger of the charge being thrown out of the converter. This was amply demonstrated in steel converter practice before small tuyeres evenly divided over the bottom were used. Messrs. Wheeler and Krejci testify to that condition in the Great Falls converter in different portions of their paper. Even without the bodily throwing out of the charge, the converter mouth is more easily fouled and the mechanical losses are greater, as the amount of shot matte thrown against the top of the converter and out of it is greater than it would be in a converter with shallow bath and into which the air is introduced in small individual jets over a large surface. The action is not so violent, as there is no concentration of a large volume of gas to a restricted area.

An increased blast pressure is also required in the vertical side-blown converter with a change in its position from the vertical. If it is tilted up, the tuyeres furthest away from the axis around which the converter is tilted will blow on a shallower matte column than those nearer that axis, and if turned down, the reverse will be the case.

With the different resistances offered to the air at each tuyere orifice, the air flow will be concentrated through the tuyeres with least resistance, and the lack of a sufficient air flow through the lower and lowest tuyeres will cause these to be filled with matte, unless the blast pressure is increased. This condition has always demanded a higher air pressure for the vertical side-blown converter than for the cylindrical, in which latter all the tuyere orifices lie in a plane through the axis around which the cylinder revolves; no matter in what position it is, the hydrostatic pressure (though this may vary in magnitude) is equal at every tuyere. It is, of course, well known that it was the lower blast pressure required by the cylindrical acid-lined copper converter that led to its wide adoption, after the Copper Queen Consolidated Mining Co. installed the "Leghorn" type of shells at Bisbee, although the first Manhès-David converters installed at the Parrot works, and generally referred to as the "Parrot" converters, marked the introduction of the Bessemer process applied to mattes in America. The vertical shell is being adopted of late, because it lends itself better structurally than the cylindrical shell to securing the magnesite lining, and to absorbing the internal strains. These features, in view of the high first cost of the magnesite lining, outweigh the disadvantages due to any increase in air pressure required.

In the bottom-blown type I propose, the converter would remain in a vertical position, blowing on a uniform height of matte bath. In Thomas converters the "needle bottom" comprises the entire converter bottom. This obliges the operator to carry from 600 to 700 mm. of pig iron charge to blow on a large charge (from 20 to 25 tons). This represents a static pressure of from  $0.06 \times 7 = 0.42 \text{ kg.-cm.}^2$  to  $0.07 \times 7 = 0.49 \text{ kg.-cm.}^2$  (6 to 7 lb. per square inch) due to the liquid iron alone, figuring the weight of molten pig iron at 7, and requires a blast pressure of from 20 to 30 lb. per square inch.

In my design this needle bottom is confined only to a portion of a converter bottom of large diameter. I would use the same size, or even a larger size, needle bottom than is customary now for the Thomas converters, but by having a total bottom area at least four times larger I can hold the same tonnage with a static column only one-quarter as high, or a larger tonnage with only a slight increase in the height of the liquid. With the tuyere block elevated, although this is not at all essential, the matte volume that can be stored is increased, and yet a shallow matte bath maintained above the tuyere orifices. This makes it possible to work with low air pressures. Due to the circulation set up, the speed of converting will be accelerated. It is for this reason that I advocate the widest possible distribution of

the air, so that it can be used efficiently on a shallow charge. For this work, turbo-blowers direct connected to electric motors or steam turbines are particularly well adapted, as they admit of wide regulation with variations in the pressure as well as air volume, for which reasons they have found extensive application in European Thomas steel works as well as for blast furnaces. For the latter, on account of the higher fuel economy of the gas engines burning blast-furnace gas, the gas-engine-driven blowing engine is still preferred, whereas for converter service the turbo-blower is preferred on account of its better and wider range of regulation. This practice is beginning to be more extensively adopted in America. I understand that turbo-blowers are used at the Great Falls Reduction Works for converter service. The use of 30,000 cu. ft. of air per minute for a converter of the size here discussed should not be considered an unusual performance in view of present-day Thomas converter practice, provided the air is distributed in the manner indicated.

#### *Tuyere Area.*

While a large aggregate tuyere area is desirable, there must be a fixed relationship between the largest area that is permissible and the air supply to the converter per minute. If this area is exceeded, then the air supply will be insufficient to keep up the required pressure; *i. e.*, it is used faster than it is supplied and the tuyeres will be filled with matte. This condition is very much that of an air receiver from which air is drawn in greater amount than it is supplied by the compressor.

The following formulæ are commonly used to calculate the weight of air delivered through iron blast furnace and converter tuyeres, and the tuyere diameter, and are also applicable to the copper converter : <sup>10</sup>

$$W = \frac{13.6 \times 60}{10\ 000} \sqrt{\frac{2g}{R}} \mu F \sqrt{\frac{(b + h_2)(h_1 - h_2)}{273 + t}}$$

$$= 0.06664 \mu F \sqrt{\frac{(b + h_2)(h_1 - h_2)}{273 + t}}$$

In which  $W$  = the weight of air in kilograms per minute delivered through the tuyeres.

$b$  = the barometric pressure in millimeters of mercury.

$h_1$  = manometer (gauge) pressure in millimeters of mercury in the wind box at the tuyeres.

<sup>10</sup> Hütte, 19th ed., vol. ii., pp. 704 *et seq.*, 712.

$h_2$  = the opposing pressure inside of the converter in millimeters of mercury; *i. e.*, hydrostatic pressure due to matte column expressed in millimeters of mercury.

$t$  = the temperature of the air in degrees C. in the tuyeres (this can be taken at 100° C., so that  $T = 373$ ).

$F$  = the area of all tuyeres in square centimeters.

$g$  = the acceleration due to gravity = 9.81 m-sec.<sup>2</sup>

$\mu$  = the coefficient of efflux. For tuyeres that are lined with smooth pipes, this can be taken at 0.8; for tuyeres in the lining, 0.75 should be taken.

$R$  is Regnault's constant = 29.4 m.-kg.

For matte with weight of 4.5, 1 mm. matte column

$$= \frac{4.5}{13.6} = 0.331 \text{ mm. Hg.}$$

For "white metal" with weight of 5.5, 1 mm. "w. m." column

$$= \frac{5.5}{13.6} = 0.4044 \text{ mm. Hg.}$$

*i. e.*, multiplying matte or "white metal" columns in millimeters by 0.331 and 0.4044 respectively, will give the corresponding mercury column in millimeters.

To figure the tuyere diameter necessary for a given working pressure, the following formula is used :

$$\frac{\pi}{4} d^2 = \frac{F}{n} = \frac{W}{0.06664 n \mu} \sqrt{\frac{273 + t}{(b + h_2) (h_1 - h_2)}}$$

in which  $d$  is the tuyere orifice diameter, and  $n$  the number of tuyeres.

#### *Air Efficiency.*

In addition to the "chemical" air efficiency, *i. e.*, the ratio between oxygen that actually combines with the impurities burned off and the amount of oxygen that is pressed into the converter, it would be interesting to know what may be termed the "volumetric" air efficiency of the Great Falls converter, *i. e.*, the ratio between the theoretical amount required to oxidize the iron, sulphur, and other impurities in the matte converted, and the amount of air actually supplied to the converter measured by engine displacement. While the air that is actually pressed into the converter is efficiently used, there are leakage losses between the engine and the tuyeres, chiefly in punching tuyeres, as the volumetric efficiency of the blowing engine working

at such low pressure should not be less than 97 per cent. While the air requirements vary with the composition of mattes, 100,000 cu. ft. of air (at standard conditions), or 850 kg. of oxygen, per ton of copper, will meet the requirements of most mattes treated at American copper-smelting works. Compared with this we have air consumptions ranging from 126,000 to 260,000 cu. ft. of air per ton of copper, or efficiencies varying between 80 and 88.5 per cent., both with acid- and basic-lined converters. This means that from 1.25 to 2.6 times the theoretically required air weight is supplied to copper converters. The first is excellent practice, the latter is poor work. At the Garfield plant of the American Smelters Securities Co., using Pierce-Smith converters, this air efficiency is reported to be around 77 to 80 per cent., which is very efficient practice.

With punching done away with in copper converting, a large source of loss of air will be eliminated, as leaks can be more effectively prevented with a tightly closed wind box without tuyere valves. Leaks would be mainly restricted to the universal air connection, which it is little trouble to keep tight when using stationary converter shells. The use of large converters minimizes air losses greatly.

#### *Mechanical and Automatic Punching of Tuyeres.*

I have previously called attention to the introduction of concentrates through the tuyeres. As these contain a varying amount of silica, slag would be formed at the very tuyere orifices, and under these conditions punching and the use of larger tuyeres would very likely become necessary. To do this punching mechanically and automatically, I have designed a tuyere-punching machine. Fig. 6 shows its salient features.

It consists of a plate to which are secured vertical tuyere-punching bars extending up into the conically enlarged tuyere pipes. The disk, or plate, with the punching bars is actuated by piston and piston rod working in an air cylinder supplied with high-pressure air (90 to 100 lb. per square inch).

All tuyeres are punched simultaneously by the forward (upward) movement of the piston and disks, the upward motion being reversed at the end of the piston stroke, when the punching bars are drawn back into a position of temporary rest.

The piston speed and the piston's upward and reversing (downward) motions are automatically controlled by a slide valve, operated mechanically from the tail rod. The time interval between punchings of tuyeres is controlled by an adjustable timing device, so that the

tuyeres can be punched at regular intervals, say every 5, 10, or 15 min., or whatever time interval is found to give best results.

As the plate with punching bars is located inside of the wind box, all tuyere valves and their leakages will be eliminated. The mechanical punching will also save the labor now used in punching tuyeres.

The air used for operating the piston, instead of exhausting into the atmosphere, preferably exhausts into the wind box at 21 to 27 lb. per square inch absolute, this terminal pressure depending on the working pressure of the air used in converting. An air receiver would have to be interposed between the converter and engine, which would act as a buffer when the tuyere pipes are momentarily partly closed during punching.

To exchange the punching rods quickly and to open the wind box and tuyere puncher to easy and quick inspection, the cast-iron plate, with its air cylinder attached, would be hinged. To let it down gradually, its travel would be controlled by a small air cylinder fastened to the converter shell, the air in which on being compressed acts as an elastic brake. To lift the plate back on to the hinged bolts the same cylinder would be used, its piston being forced back by compressed air.

The tuyere pipes would have bushings of chilled iron or manganese steel to prevent too rapid wear.

If concentrates are to be blown into the converter and the converting speed is not to be seriously retarded the air requirements have to be greatly increased. This is evident from figuring the oxygen requirements of the concentrate itself. A concentrate with Cu, 18; SiO<sub>2</sub>, 25; Fe, 26; Al<sub>2</sub>O<sub>3</sub>, 5; and S, 30 per cent., would require, theoretically, 37.5 kg. of oxygen for every 100 kg. of concentrate, or 163 kg. of air, which is about 130 cu. m., or 4,600 cu. ft. If we were to treat 100 kg. of concentrate per minute, at least this amount of air would have to be supplied in addition to what is needed for converting the matte.

When treating a low-grade matte, very siliceous copper concentrates high in copper are very desirable, as these will displace siliceous ore usually fed through the converter mouth, and at the same time enrich the matte. Such a concentrate is that produced by the Miami Copper Co., and which was treated in this manner by the Cananea Consolidated Copper Co.

In view of the great future this practice has, large converters that can utilize efficiently and at moderate air pressure very large volumes of air will undoubtedly find increasing application in copper-smelting works.

*Tuyere Bottom.*

In Fig. 6 this bottom is made up of segments and held in place by a series of inverted arches. These arches will be tightened by the hydrostatic pressure of the matte, "white metal," or blister-copper; this pressure will correspond to that exerted by a column of liquid of the same height as the height of these arches. This pressure is about 4 lb. per square inch for matte and a total of about 1,700 lb. per arch. It may increase to nearly 7 lb. per square inch and 3,000 lb. per arch with blister copper. A better method of constructing the tuyere bottoms is that used by Thomas steel works, and as they have had 34 years' experience in the use of basic linings, their practice can be followed with profit. These bottoms are preferably made as a monolith and pressed into place with a hydraulic ram. A number of these are kept on hand, and the converter is so designed that they can be inserted and removed through the wind box. The distribution of so large a volume of air through this bottom, coupled with the low temperature at which a copper converter is blown, should not be without beneficial influence on the life of the bottom, as it should be cooled sufficiently to prevent too rapid erosion. After all, it is the magnesite consumption and cost per ton of copper that counts, and if by increasing the speed of converting the life of the lining should be decreased, consumption per ton of copper does not necessarily have to increase. In Thomas converters they treat tonnages with a converting speed that has as yet not been equaled in any copper-converting plant, and while their magnesite bottoms go faster, the consumption of magnesite per ton of steel is not greater than that per ton of copper in copper converters. It should be borne in mind that the work is very much more severe, with temperatures of 1,600° C. toward the end of the blow. This matter of constructing the tuyere bottoms I shall discuss more fully in my paper referred to above.

The building of so large a converter and the great increase in converting speed made possible thereby is undoubtedly one of the most important recent advances in copper metallurgy, and a great deal of credit is due Messrs. Wheeler and Krejci for their achievement.

With this large converter making possible the use of large air volume at low pressure they are nearer the realization of John Hollway's ambition to smelt pyrite ores in the "converter" without the use of fuel save that furnished by the pyrite.

REDICK R. MOORE, Mexico City, Mexico (communication to the Secretary \*):—Messrs. Wheeler and Krejci have given an extremely

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\* Received Sept. 18, 1913.



valuable history of the development of converter practice at Great Falls, Mont., and a *résumé* of the experiments which have led up to their present practice, which may be characterized as large upright converter vessels with basic lining and large tuyere area—the latter obtained by greatly increasing the diameter of the tuyeres as well as their number. They, however, do not give any data as to matte and slag analyses, blast pressure, utilization of blast volume (piston displacement), interior area of the tuyeres after protracted use, nor frequency of punching and size of punch bars used.

It seems to me that the addition of these figures would complete and enhance the value of their paper.

There must be sufficient blast pressure to overcome the static head of the column of matte and slag in the converter vessel and the friction head in tuyeres and pipes, together with an excess as a safety factor.

Excessive blast pressure results in a loss of both power and air efficiency (the latter on account of excessive leakages), and also, with tamped linings, in irregular wear.

At Aguascalientes, in 1904, experiments were made to determine the effect of enlarging the tuyere area, with a view to the reduction of power costs, and to determine the height of matte column above the level of the tuyeres necessary to secure the utilization of the oxygen of the blast.

The results of these experiments were presented to the Institute in a paper written in 1907, but not published. Briefly, the enlargement of the tuyeres to 1.25 in. in diameter, from about 0.75 in., resulted in a reduction of the blast pressure from about 18 lb. to about 12 lb., and an increase in production of about 20 per cent., maintaining the same engine speed. At the same time the life of the acid lining was increased greatly on account of more even wear and the absence of float silica.

Tuyeres 1.5 in. in diameter proved unsuccessful, as they weakened the lining too much and the end ones filled up in turning up to blow.

To secure the benefits of the enlarged tuyeres it was necessary to punch them frequently with a bar nearly the size of their diameter. The bar used was 0.75 in. in diameter with a head about  $1\frac{1}{2}$  in. in diameter.

The Aguascalientes converters were 8 ft. in diameter by 16 ft. upright, acid lined, and when newly lined were 3 ft. in diameter at the tuyeres.

The utilization of the oxygen of the blast (engine displacement)

varied from 67 to 83 per cent., with an average of six tests of about 75 per cent.

The delivery of air by the engine, as calculated from "cards" of the air end by the Master Mechanic, was 98 per cent. of the displacement.

It was calculated from the results of measurements and weights that with 6 in. of matte above the tuyeres the utilization of the oxygen of the blast was practically complete in these converters with an engine displacement of 5,600 cu. ft. per minute; barometer, 23.6 in.; temperature, 33° C.

The reduction of blast pressure was not in proportion to the increase in nominal tuyere area, even when punching with 1½-in. headed rods, because of the formation of crusts in the tuyeres near their mouths and the formation of "noses," but the results were very gratifying.

The analyses given by Wheeler and Krejci (pp. 1874 to 1876) do not seem to conform to the theoretical. The table shows the ordinary converter reactions, together with the gases resulting if the oxygen of the blast is completely utilized for combustion.

The predominating reactions in the first or slagging period of converting copper-mattes are II and III of the accompanying Table I, while the subsidiary reactions I, IV, V, VI, VII, X, XIII, and XV to XXI, are going on simultaneously.

As the formation of  $\text{Fe}_3\text{O}_4$ , as shown by the products, is in excess of the reaction IV, the average gases for the period should contain more than 13.04 per cent. of  $\text{SO}_2$  by volume and less than 13.90 per cent. In the second period of converting (white metal to copper) the predominating reactions are VIII and IX, while the subsidiary reactions XI, XII, XIV, XVI, and XVIII are going on simultaneously. As the formation of  $\text{Cu}_2\text{O}$ , as shown by the products, is in excess of the reaction XI, the average gases for the period should contain less than 20.8 per cent. of  $\text{SO}_2$  and more than 19 per cent.

Throughout the operation the gases should contain free volatilized sulphur,  $\text{PbS}$ ,  $\text{ZnS}$ , and  $\text{AsS}$ , as shown by the equations I, XVI, XVII, XVIII, and XIX.

With volumes of from 5,000 to 12,000 cu. ft. of air per minute (engine displacement), I have determined qualitatively the presence of these compounds in the converter gases. This is evidence that there was a complete utilization of the oxygen of the blast.

I have previously explained my reasons for believing that there is no  $\text{SO}_3$  in converter gases.<sup>11</sup>

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<sup>11</sup> *Engineering and Mining Journal*, vol. xc., No. 6, p. 264 (Aug. 6, 1910).

A great many of the analyses given show wide differences from the theoretical and we are forced to the conclusion that either the theory is wrong or the analyses are wrong.

Not having any slag analyses, it is impossible to calculate any value for the  $\text{CO}_2$  in the gases from the decomposition of carbonates, but from the slag analyses of a previous period, showing only 0.7 per cent. of  $\text{CaO}$ , in the slag, it would seem that the  $\text{CO}_2$  in the gases would be a negligible quantity.

The  $\text{CO}_2$  from the atmosphere would be undeterminable by the ordinary methods of gas analysis.

It would seem to be very desirable to rigorously verify the analyses or determine the sources of error.

Table I.—Converter Reactions.

|        |                                                                      |                                                                      | Volatilized. | Gas.              |           |
|--------|----------------------------------------------------------------------|----------------------------------------------------------------------|--------------|-------------------|-----------|
|        |                                                                      |                                                                      |              | SO <sub>2</sub> . | N.        |
|        |                                                                      |                                                                      |              | Per Cent.         | Per Cent. |
| I.     | 5 FeS + Heat                                                         | = Fe <sub>3</sub> S <sub>4</sub> + S.....                            | S.           | .....             | .....     |
| II.    | Fe <sub>3</sub> S <sub>4</sub> + Cu <sub>2</sub> S + O <sub>13</sub> | = 5 FeO + Cu <sub>2</sub> S + 4 SO <sub>2</sub> .....                | .....        | 13.90             | 86.1      |
| III.   | Fe <sub>3</sub> S <sub>4</sub> + O <sub>14</sub>                     | = 2 FeO + Fe <sub>3</sub> O <sub>4</sub> + 4 SO <sub>2</sub> .....   | .....        | 13.04             | 86.9      |
| IV.    | 2 Fe <sub>3</sub> O <sub>4</sub> + Cu <sub>2</sub> S                 | = 6 FeO + Cu <sub>2</sub> S + SO <sub>2</sub> .....                  | .....        | 100.00            | .....     |
| V.     | Fe <sub>3</sub> O <sub>4</sub> + Fe <sub>3</sub> S <sub>4</sub>      | = 4 FeO + 4 FeS.....                                                 | S.           | .....             | .....     |
| VI.    | Fe <sub>3</sub> S <sub>4</sub> + Cu <sub>2</sub> S + O <sub>11</sub> | = 5 FeO + Cu <sub>2</sub> S + 3 SO <sub>2</sub> .....                | .....        | 12.52             | 88.4      |
| VII.   | 5 FeS + Cu <sub>2</sub> S                                            | = Fe <sub>3</sub> S <sub>4</sub> + Cu <sub>2</sub> S.....            | .....        | .....             | .....     |
| VIII.  | Cu <sub>2</sub> S + O <sub>3</sub>                                   | = Cu <sub>2</sub> S + SO <sub>2</sub> .....                          | .....        | 20.8              | 79.2      |
| IX.    | 4 Cu <sub>2</sub> S + O <sub>3</sub>                                 | = Cu <sub>2</sub> S + Cu <sub>2</sub> O + 4 SO <sub>2</sub> .....    | .....        | 18.52             | 81.4      |
| X.     | Cu <sub>2</sub> O + Fe <sub>3</sub> S <sub>4</sub> + O <sub>12</sub> | = Cu <sub>2</sub> S + 5 FeO + 4 SO <sub>2</sub> .....                | .....        | 14.90             | 85.1      |
| XI.    | 2 Cu <sub>2</sub> O + Cu <sub>2</sub> S                              | = Cu <sub>2</sub> S + SO <sub>2</sub> .....                          | .....        | 100.00            | .....     |
| XII.   | Cu <sub>2</sub> + O                                                  | = Cu <sub>2</sub> O.....                                             | .....        | .....             | 100.0     |
| XIII.  | Fe + O                                                               | = FeO.....                                                           | .....        | .....             | 100.0     |
| XIV.   | Cu <sub>2</sub> S + H <sub>2</sub> O                                 | = Cu <sub>2</sub> O + H <sub>2</sub> S.....                          | .....        | .....             | .....     |
| XV.    | FeS + H <sub>2</sub> O                                               | = FeO + H <sub>2</sub> S.....                                        | .....        | .....             | .....     |
| XVI.   | 2 H <sub>2</sub> S + SO <sub>2</sub>                                 | = 2 H <sub>2</sub> O + S.....                                        | S.           | .....             | .....     |
| XVII.  | 3 ZnS + O <sub>3</sub>                                               | = 2 ZnO + ZnS + 2 SO <sub>2</sub> .....                              | ZnS          | 14.90             | 85.1      |
| XVIII. | 2 PbS + O <sub>3</sub>                                               | = PbO + PbS + SO <sub>2</sub> .....                                  | PbS          | .....             | .....     |
| XIX.   | 3 Fe <sub>3</sub> As + 10 FeS + O <sub>15</sub>                      | = 22 FeO + As <sub>2</sub> O <sub>3</sub> + 9 SO <sub>2</sub> + AsS. | AsS          | 9.80              | 90.2      |
| XX.    | CaCO <sub>3</sub> + Heat                                             | = CaO + CO <sub>2</sub> .....                                        | .....        | .....             | .....     |
| XXI.   | 2 MO + SiO <sub>2</sub>                                              | = (MO) <sub>2</sub> SiO <sub>2</sub> slag.....                       | .....        | .....             | .....     |
| XXII.  | S + O <sub>2</sub>                                                   | = SO <sub>2</sub> .....                                              | .....        | 20.80             | 79.2      |

## Development of the Basic-Lined Converter for Copper Mattes.

Discussion of the paper of E. P. Mathewson, presented at the Butte Meeting, August, 1913, and printed in *Bulletin* No. 78, June, 1913, pp. 1033 to 1037.

PROF. JOSEPH W. RICHARDS, South Bethlehem, Pa. :—Speaking to the question of the development of the basic lining, and speaking from a somewhat considerable study of the history of the process, I think Mr. Mathewson's conclusion (in the last paragraph of his paper) is perfectly justified and is very fairly stated. Messrs. Smith and Pierce worked at developing their process for many years; copper men had been trying their level best to get away from the silica lining of the converters and had uniformly failed. On one page of Mr. Mathewson's paper we read that at the old works of the Anaconda Company, at Anaconda, the experiments "were abandoned on the score of cost and lack of advantages." On the next page, after describing the work of Messrs. Smith and Pierce, we have the statement that the Anaconda Company lined a shell with magnesite brick and "the results were excellent." I think Mr. Mathewson's statement that to Smith and Pierce belongs the credit of developing a long-discredited idea, is correct.

C. D. DEMOND, Anaconda, Mont. :—It seems to me that the matter of the lining is important; my impression is that they used tar in their basic lining and that did not seem to be at all successful at Anaconda, but silicate of soda was very successful.

MR. RICHARDS :—I did not know that they had abandoned the use of tar.

MR. DEMOND :—I said I thought that was the practice. At Anaconda that was not at all satisfactory in the basic linings. Silicate of soda was very satisfactory and is so.

HERMANN A. KELLER, New York, N. Y. (communication to the Secretary \*) :—I have read Mr. Mathewson's paper on basic-lined converters with much interest. My experiments at the Parrot Works of Butte, which Mr. Mathewson refers to, I believe, were made in 1892, and were published by me in Dr. Peters's *Modern Copper Smelting*.<sup>1</sup>

The magnesite bricks then used were directly imported from

\* Received Aug. 7, 1913.

<sup>1</sup> 1893 edition, pp. 570, 571.

Greece and naturally were very costly, and slow to obtain. I discontinued the practice at the time, because I considered our converter shells too small to hold sufficient amounts of heat without the aid of additional heating produced in slagging off the iron in the matte by the silica in the lining, thereby increasing the capacity of the converter with each additional charge until the lining had become so thin as to endanger the shell. The initial charges usually produced from three to five bars of blister copper, weighing about 110 lb. each, while it occurred frequently that the final charges of a well-made lining produced from 15 to 20 such bars. In order to increase our heat units still further we frequently resorted to the practice of throwing into the molten charge additional green matte and scraps, just prior to the final blow.

The size of the tuyeres may have considerable importance with basic-lined converters, as Mr. Mathewson points out, but I cannot speak from experience as to this point.

1891 and 1892 were years of considerable metallurgical improvement at Butte. Not alone did we modernize the converter practice during this period, but mechanical roasters of greatly increased capacity were also devised, besides constructing much larger reverberatory furnaces and installing coarse Harz jigs (known as bull jigs), with the double object of reducing concentration losses and to produce more material suitable for blast-furnace use.

Prior to the time of the above experiments the Parrot Works were about the only plant in this country that was converting copper upon a large scale. This was done under the original Manhès patents, which consisted principally in raising the tuyeres some distance above the bottom of the shells, differing thereby in construction from those used in the metallurgy of iron, which latter were also much larger. The Anaconda Works at that time Bessemerized on a more limited scale and in different shaped converters, partly because they thought a more square shaped vessel would have greater advantage, and partly perhaps to circumvent, if possible, Manhès's patents under which the Parrot Company was operating. Cylindrical converters of much larger size were installed at Great Falls subsequently, and the barrel or Leghorn type of converters was introduced still later in this country. I might add here that some of the most recent installations have returned to cylindrical shells of the original Parrot type, only much larger.

From my experience I should consider that almost any kind of converter shell that is suitable for acid lining can readily be adapted to basic lining, provided it is sufficiently large to carry its own heat

throughout the process. In fact, my belief is that the recent successes with basic converter linings are the direct outcome of the larger vessels, which are necessitated by the newer plants to handle larger quantities.

E. H. HAMILTON, West Norfolk, Va. (communication to the Secretary \*):—In regard to Bessemerizing leady copper mattes: August Raht built a basic-lined converter at the Philadelphia Smelter, Pueblo, Colo., about 1895, and figured on catching fume in a long flue. I was present one day when the "pour" did not appear on the converter being turned over.

In 1900 Mr. Knox, at Ely, Vt., in attempting to operate a Garretson furnace (to make copper in the crucible of the blast furnace) lined the crucible with magnesite brick and predicted that magnesite would be the solution of the question.

A good deal has been written recently about detachable hoods to eliminate accretion and also about flames. If a basic-lined converter plant is designed properly there will be no hood accretions, and if run to best advantage there will be practically no flame visible.

The quickest blown charges in acid-lined converters of which I have records might be said to be blown in the dark. Of course the fume, etc., from sulphur, lead, zinc, etc., is visible. The workmen object to this method as they want to see "something doing."

I would like to ask Mr. Mathewson what is the analysis of gases from the basic-lined converter, as it affords an opportunity to obtain a long steady run under more uniform conditions than formerly in the acid-lined converters. Some years ago we found the oxygen content of the gas from matte in acid-lined converters to be as follows:

|                                     | Per Cent. |
|-------------------------------------|-----------|
| First half of the first blow.....   | 0.1       |
| Second half of the first blow.....  | 1.0       |
| First half of the second blow.....  | 9.0       |
| Second half of the second blow..... | 17.0      |

It would be interesting to know the percentage of nitrogen,  $\text{SO}_2$ , etc., from a basic-lined converter operated under present methods.

I understand from the paper that the  $\text{MgO}$  and  $\text{CaO}$  in the converter slag cannot be controlled, but that the  $\text{Fe}$  and  $\text{SiO}_2$  can be controlled within certain limits. Can the gases be controlled? Varying the iron in the slag no doubt will affect the gas to some extent.

To what extent can converter gases from basic-lined converters be made available for the manufacture of sulphuric acid?

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\* Received August 8, 1913.

L. O. HOWARD, Globe, Ariz. (communication to the Secretary \*) :— When we started running our 12-ft. converter we had a great deal to learn and the shell got some hard usage. The tendency at first was to use large charges which raised the back pressure and plugged the tuyeres. Later on, due to the men carelessly tilting the shell too far back when punching out tuyeres, copper ran into the pipes and we lost several more. Frequent renewals caused the brick to chip off in places and for a time it looked as if the wear at the tuyere line would be greatly in excess of any other part. This, however, did not prove to be the case and the accompanying diagram, Fig. 1, shows a good thickness of brick along this section when they had given out at other places. Doubtless the cooling action of the air helped.

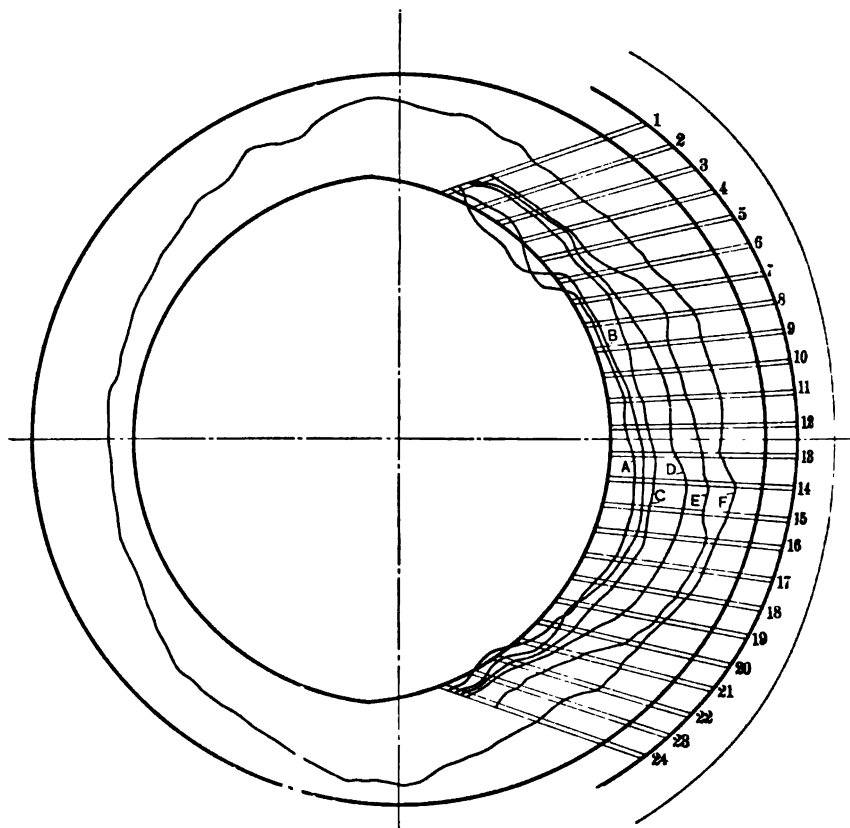
In making this diagram the measurements were taken by turning the converter down and dropping a rod through the tuyeres until the end was just visible. When measurements *A* and *B* were taken, the covering seemed to have been well removed, but it will be noticed that considerable remained on at the end tuyeres. This, of course, made these figures worthless as a gauge for the wearing brick. Subsequently when measurements were taken, care was taken to remove all the coating and expose the naked brick.

Shortly after we had reached the 2,000,000 mark I stumbled across the fact that it was possible to coat the brick with magnetic iron oxide and thereby build up a protective coating. At one time we had, by actual measurement, 15 in. of this covering the brick, but it so lessened the capacity of the shell that we had to take it off and put on a thinner one. Our great difficulty now is making the men keep the temperature down, as a short run with a high heat will clean everything off and expose the brick.

We have found it quite possible to keep this coating in place for many days at a time, during which period no sign of brick could be seen. Once with our first shell we ran for six weeks without a brick showing. Up to the present, however, we have been unable to keep a coating on indefinitely, as the men sometimes let a charge get very hot and melt it off. When too thick at the tuyeres it makes punching more difficult and for this reason it is not looked upon with favor by the help.

With 14,500,000 lb. of copper to the first patching, we should get 20,000,000 for the total life of the lining. Two places, one on each side of the converter, and a place 4 ft. long above the tuyeres showed greatest wear and gave out simultaneously. Later inspection showed that the lining had remained in place until less than 2 in. in thickness.

\* Received Aug. 15, 1913.



Measurements taken at intervals during life of lining to first patching. Matte average = 43.9 per cent. of copper.

- A. After making 4,000,000 lb. of copper.
- B. After making 6,000,000 lb. of copper.
- C. After making 6,000,000 lb. of copper.
- D. After making 10,000,000 lb. of copper.
- E. After making 12,000,000 lb. of copper.
- F. After making 14,501,962 lb. of copper.

Brick was kept coated with  $\text{Fe}_2\text{O}_3$ . Measurements Nos. 1 and 2 were taken with this coating in place. For all subsequent measurements it was, as far as possible, removed. Brick finally gave out at back about 20 in. above tuyeres. Shell in operation from January 6 to June 29, 1913.

FIG. 1.—DIAGRAM SHOWING WEAR ON BRICK AT TUYERE LINE IN A 12-FT. GREAT FALLS TYPE BASIC CONVERTER.



The shell was in continuous use for 173 days and made 664 charges, averaging slightly less than 11 tons of copper per charge. No transfers were made to it.

Our converting equipment consists of one 12-ft. stand (with which we endeavor to do all our work) and two 10-ft. 6-in. stands to be used as reserves. For the latter we have lined two of the old shells with magnesite brick. As our daily copper production is rather irregular, we sometimes find it necessary to relieve the 12-ft. shell by blowing one of the smaller size. This, however, is only done when the production runs over 50 tons per day for several consecutive days. The 12-ft. shell gets no rest between charges other than the time taken to punch out tuyeres and pull collars; perhaps one-half hour per charge. The record for this shell is 66.4 tons of copper in 24 hr. with a 52 per cent. copper matte, and 60 tons per day for three days with a 47.7 per cent. matte. For a period of three months we averaged slightly over 47 tons of copper per day. Matte averaged 43.8 per cent. Frequently we will run for two or three weeks without blowing the small shells. From this it will be seen that it is impossible to favor the converter either by transferring or by allowing it to cool between blows.

BANCROFT GORE, Butte, Mont. (communication to the Secretary \*):  
—With reference to the small basic-lined converters installed at Gatico, Chile, February, 1912, I am pleased to present the following details:

These were of the barrel type; dimensions over all, 58 in. diameter by 84 in. long; hand-tilted by means of pinion and rack passing half round the converter at its center. The mouth was at the center, tapering to 28 in. in diameter.

For tuyeres, each was equipped with 18 hydraulic tubes, 1 in. internal diameter by  $\frac{1}{4}$  in. thick, spaced 4 in. center to center and projecting 11 in. into converter. From the length over all we must deduct from each end  $\frac{3}{8}$  in. for the thickness of the steel shell,  $4\frac{1}{2}$  in. for one layer of magnesite arch brick cemented fast to shell by a thick mixture of sodium silicate and finely ground dead-burnt magnesite, and 6 in. for the protective coating of highly refractory basic slag formed under the conditions of operation and containing: CuO, 6.4; FeO, 78.5; SiO<sub>2</sub>, 5.0; CaO, 1.8; Al<sub>2</sub>O<sub>3</sub>, 3.5 per cent. This gave a space about 5 ft. 4 in. long for the movement of the bath, or 8 in. between last tuyere and slag wall at each end. One layer of No. 1 arch brick was used throughout except for the region 12 in. above and below

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\* Received Sept. 17, 1913.

the tuyere zone, which had two layers of "straights." One shell was lined with two layers, making 9 in. of magnesite throughout, but it was found to have too small a capacity, especially after the growth of the protective coating mentioned above. This coating formed also on the bed of the converter and under adverse conditions would rise to within a few inches of the tuyeres. Blast pressure was 12 lb. No provision was made for the expansion of the brick, a matter of little importance in this size of converter.

The high conductivity of these brick cemented fast to the shell and the large area of this shell exposed to the cooling influence of the atmosphere, considering the relatively small bath, both favored the formation of this slag coating, which, when operating on a 45 per cent. copper matte, remained at a uniform thickness of about 6 in., thereby preserving indefinitely the life of the bricks except at the tuyere zone, where they were renewed about twice a year.

When the matte contained much less than 44 per cent. of copper the reaction temperature within the converter increased and the coating would gradually disappear, exposing the bricks, and at this stage their life was only a few days, unless the grade of matte could be raised to near 50 per cent., when a coating would rapidly form. After this protective coating was once in place the matte could be lowered to from 44 to 47 per cent.

Under normal conditions the converters took about 6,000 lb. of matte (in two charges), yielding more or less 2,500 lb. of copper at each pouring.

Without the protective influence of the slag coating and with the bricks plainly exposed to view, the converter took as high as 22,000 lb. of matte (in three charges), yielding more or less 8,800 lb. of copper at a pouring. The speed of combustion working with this large bath of 40 per cent. matte increased very notably the temperature of the converter. Thus, when finishing for copper no punching was needed, as any noses forming were melted immediately. As mentioned above, the life of a lining under these conditions was only a few days.

Perhaps, if we had reduced the diameter of the tuyeres to  $\frac{3}{4}$  or  $\frac{13}{16}$  in., thereby slowing down the speed of combustion and restoring the balance between heat radiated and heat formed within the converter when blowing on these low mattes, the same slag coating mentioned above would have formed and saved the bricks. As our smelting conditions at Gatico seldom gave low mattes owing to the abundance of oxidized ores on the charge, we did not try to perfect a small converter that could handle these mattes.

As these magnesite bricks at Gatico cost us about 25 c. U. S. each, and served only as a backing for the growth of the basic coating, which after the first blow hid them permanently from view, it seemed possible that some substitute might be used, and in this connection I thought of the much cheaper "bauxite" brick. I would like to hear from some one who has tried them in furnace work, especially at points where both chrome and magnesia have failed to make good.

I would not advise the construction of converters smaller than those at Gatico, as even a few accidental charges of matte containing over 52 per cent. of copper would form such a thick coating of slag at the ends and on the bed that several tuyeres would be lost and the capacity reduced to the point where low-grade matte could not come to the rescue owing to the lack of sufficient mass reaction.

RALPH BAGGALY, Pittsburg, Pa. (communication to the Secretary \*):—I am sorry that I cannot agree with Mr. Mathewson in his conclusions. I cannot, for the reason that I personally know that these conclusions are not correct.

The basic-lined converter and the feeding of silica (either mineral-bearing or barren) into the matte, in lieu of destroying the silica lining, are so closely linked that they may be treated as twins.

At the time I took up a study of the metallurgy of copper (about 1900), all of the authorities—Dr. Hermann Keller, Dr. Peters, Dr. Douglas, the Amalgamated experts, the Guggenheim metallurgists, etc.—pronounced the dissolving of ores in matte impossible. Mr. Hixon called it suicide. Dr. Keller has several pages of explanations in Dr. Peters's book as to just why it was impossible.

John Hollway tried it in 1878, and he met with considerable success. If his backers (the Matthewsons of Wales and London) had provided him with such a converter as he then described (*i. e.*, with the tuyeres elevated on the sides and a quiescent pool below, in which the copper could accumulate without clogging his tuyeres), he would have succeeded beyond any doubt.

Four years later (1882), Pierre Manhès made a converter, as fully described by John Hollway in 1878, and forsooth called it "the Manhès converter," and obtained patents on it in France, England, the United States, etc. In 1882, Manhès attempted to feed silica into the matte, both through the tuyeres and into the nose of the converter. He scored a complete failure in both. The former is the present J. Parke Channing process, with which Miami concentrates are now treated.

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\* Received July 15, 1913.

The sand-blast action is injurious to the tuyeres and the values are not extracted by the matte. In order to recover these values, a subsequent melt of the slag in a blast furnace, or in some other form of furnace, is necessary. Why then repeat Manhès's failure?

I invented the so-called Knudsen process before he did and I discarded it because of its defects and its useless expenses. I fully described all of these things in an article that I wrote for the *Anaconda Standard*, Aug. 18, 1905. On June 21, 1890, Jared E. Gaylord applied for a patent both on a mineral-bearing silica lining and on feeding ore into the matte; in the latter he failed completely.

Dr. Keller then attempted the same thing at the Parrot smelter, Butte, and failed. His own account of this failure is given in Peters's *Modern Copper Smelting* (1895 ed.), p. 570 *et seq.* The same thing was tried at Great Falls and failed. The same thing was tried by Hixon at the old Marcus Daly smelter, Anaconda, and in his book (p. 81) he says: "The silicious lining is as much a part of the process of copper converting as magnesia lining is in the basic Bessemer treatment of phosphoric iron, and it is suicidal to attempt any other kind of lining, either water-jacketed or basic. The improvement, if there is to be any, is to be in the line of mechanical devices, and the use of silicious ores to replace the expensive quartz and clay linings."

This must be the experiment for which Mr. Mathewson gives E. A. C. Smith credit. However, it is not important just who conducted this experiment. The result was a total failure and it simply confirmed the general belief that this new art was impossible.

This was the "state of the art" the world over at the time I commenced work at Butte. There were absolutely no basic-lined converters in use for converting copper mattes and absolutely no one was feeding and dissolving ores in a bath of matte. Many had tried it and all had failed. The nearest approach to it was the use of a mineral-bearing lining, at Aguascalientes and as patented by Gaylord in 1890. A lot of misleading stuff has been published about my work while at Butte and since. The facts are:

1. The apparatus furnished me by my associates was small and bought solely for experiment; neither furnace nor converters were intended to make copper on a commercial scale. After I proved that I could dissolve ores in a basic-lined converter, I was then given my "Jumbo converter," in which I worked up every pound of ore I had, without regard to its grade or silica contents. But even then I had no furnace that was much bigger than a bake-oven, or in which one could afford to make copper commercially.

2. We bought up a lot of patents, such as Allen's, Potter's, Gaylord's,

Garretson's, etc., solely to get them out of the way of patents I intended applying for. It was not intended by me to use any of them. I well knew that they had all been tried and had failed. Garretson was a very hard man to deal with, and in order to get his patents out of the way I was compelled to agree to test his process to a finish. We attempted this at Ore Knob, with Bellinger in charge, but we were compelled to admit, as Garretson claimed, that it was not an actual test. We then let Bellinger make another test at Vancouver Island. The whole plant was so defective that they had neither steam nor air. Garretson still demanded his "pound of flesh as nominated in the bond!" We then decided that I should comply with the terms of his contract by conducting these tests myself at Butte. With this object in view, we built the little furnace in which I later (as soon as I had any ore) made five series of tests of Garretson's process, and then and there proved that it was inoperative and that it would freeze the furnace solid every time it was attempted. In other words, the blowing of a converting blast into 85 per cent. of slag (an oxide) had a greater chilling effect than the heating of 15 per cent. of matte (a sulphide) could overcome. The situation was, of course, aggravated by his column of ores, etc., standing in the matte.

Dr. Herreshoff and I had discussed these things and he later said that my tests had simply developed and made clear five or six more defects in the Garretson process than either of us had been able to foresee.

3. My troubles at Butte were due to the fact that I had no ore to treat, because the acid water and a lack of money delayed the development of the ore.

4. As soon as I got my Jumbo converter and a blowing engine that would work without breaking down every day, I commenced making excellent blister copper, and I continued this for  $8\frac{1}{2}$  months, until every pound of ore in our bins or that I could buy had been worked up. I did this work too with one single basic lining (see Heywood's report in *Engineering and Mining Journal*, Mar. 24, 1906).

This was the first time in the whole history of the metallurgy of copper that mineral-bearing ores were successfully fed into the matte, as a means of removing the iron through the formation of silicate of iron slags in lieu of destroying the silica lining. It also included, of course, the successful use of a permanent, basic-lined converter. When our workmen announced in Butte that I was making copper by this new process no one would believe it. Fritz Heinze was the first to investigate and he was also the first to use my new pro-

cess. Later Mr. Thayer brought Mr. Mathewson to visit me; Mr. Mathewson no doubt still remembers our discussion. Later Mr. Mathewson sent his assistant to our Pittsmtont smelter, who spent parts of three days with us learning all of the details of this new art.

I left Butte about eight years ago and I have never been back there. Shortly after my return to Pittsburg I received a personal letter from Dr. Hermann Keller, in which he asked me to meet him at the Engineers' Club in New York on important business. I did this, and he took me to the offices of the American Smelting & Refining Co. I was introduced to Anton Eilers. He at once sent a messenger for August Raht and two other experts, whose names I did not learn. They may have been Messrs. Smith and Pierce, although I do not know this to be a fact. At all events, the office was cleared of all save these five experts and myself. We then commenced a discussion on methods of treating copper, which extended over two days. They all disputed the correctness of my theories. I told them I had been actually practicing this new art for  $8\frac{1}{2}$  months and that I had only used one single basic lining in all of that time. They then asked me to build a plant at one of their smelters and demonstrate the correctness of my theories, on their agreement to adopt this new process at 16 of their smelters. My reply was that unfortunately my old patents were owned, for the districts where most of their smelters were located, by the Pittsburg & Montana Copper Co. They took down the name and address, and later they bought the company's rights under some of these patents.

Some time after this I again met August Raht; this time as the consulting metallurgist of August Heckscher. He told me that none of the Guggenheim experts could believe that I could dissolve ores or silica in a matte bath in a basic-lined converter; However, on my positive statement that I had been practicing this new art for  $8\frac{1}{2}$  months and by it had produced more than \$500,000 worth of copper, within 80 days after my visit they commenced a series of tests of my theories in their Baltimore smelter, and I am told these tests were made by Messrs. Smith and Pierce, who were employed at the smelter in Baltimore. These tests proved that my theories were correct and the Guggenheims then brought out, on my old patents as a basis, what they facetiously called the "Smith and Pierce process." This process was quickly introduced at Baltimore, Perth Amboy, Omaha, Salt Lake, etc. I can prove by such men as Arthur S. Dwight, Dr. J. B. F. Herreshoff, Robert S. Towne, William A. Heywood, and many others, that I alone produced this revolutionary change in the metallurgy of copper, and I did it in direct opposition to the recorded

opinions of all the authorities. However, public acknowledgment of the facts in this matter has been published, and by the very authorities who for years had pronounced this feat impossible.

In Dr. Peters's *Principles of Copper Smelting*, p. 465, he says: "As Mr. Baggaley is the originator of the method and Mr. Heywood is the technical manager, their views regarding the process might, naturally, be expected to be less impartial than those of an outside engineer; but it is evident that they are doing regularly what the profession, in general, has regarded as impracticable; namely, converting a very low grade matte in a vessel having a permanent basic lining, and supplying it with silica from outside sources."

In the light of all the foregoing facts, what basis of truth is there for the statement that "To Smith and Pierce belongs the credit of taking a long-discarded idea and developing it into a successful process?"

What have Smith and Pierce invented or developed? I practiced the art with perfect success for  $8\frac{1}{2}$  months, using a single lining, years before they even commenced to test the correctness of my theories and which theories all of their own experts disputed. As a well-known authority has stated to me, all of Smith and Pierce's patents for "improvements" on my process are really "steps backward." Their design and construction are such that it is impossible to hold their lining or tuyeres in place. Their practice, I am told, compels them to reline every 45 days, never over 60 days. Their attempt to prolong the life of their lining by their patented addition of 15 per cent. of cold ore really means "reduced efficiency!"

The business end of our old company was a failure from the start and the result has been that I have never made a cent out of any of my inventions and my 13 years of study and effort. In the present paper, even the credit for this revolutionary change is given to others. When I left Butte, my contract with the old company terminated, and since then (for eight years) I have been studying this subject and developing improvements. I wish, in this connection, to record my opinion that there is really no good converter, built on scientific principles, in existence to-day. My old Jumbo at Butte is the best one, but it would not stand the service in my latest inventions.

This problem will not be finally solved until my continuous process is used. The heats must not be held down to  $2,100^{\circ}$ , as is claimed in this paper, thus reducing the efficiency, but, on the contrary, must be driven to the utmost limit. Apparatus must and can be provided that will stand this severe service and it will not be such as Mr. Mathewson pronounces "standard" at Great Falls, with an expensive

lining  $2\frac{1}{2}$  ft. thick. A 12-in. lining or even an 8-in. lining is ample, providing the design and construction are such that it can be held in place absolutely and providing ample provision is also made for radiating and dissipating these excessive heats from the outside of the vessel, instead of doing what all are now doing,—attempting to regulate these on the inside of the vessel.

I can show how all of these things can be safely and cheaply done. I can also show a mechanical tuyere puncher that will do far better work than men can; will do it almost without cost—compared with hand-work—and will do this efficiently year in and year out. As the modern converter is equipped with from 24 to 68 tuyeres, the punching becomes a laborious and expensive task.

My latest converter is cheap to build; it is absolutely rigid and secure in every respect. I am certain the lining will last for a year and I believe much longer. My old lining lasted  $8\frac{1}{2}$  months. The process is continuous, and an absolute limit can be placed on the corrosion of the lining and to any degree desired without in any way interfering with successful converting up to the final stage of blister. It is difficult to do these things and do them in a perfectly safe way.

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### A Note on the Occurrence and Manufacture of Refractories in Montana.

Discussion of the paper of W. H. Gunniss, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 81, September, 1913, pp. 2309 to 2310.

PROF. J. W. RICHARDS, South Bethlehem, Pa. :—In regard to the physical nature of quartz for making silica brick, is the coarse-grained preferable?

E. P. MATHEWSON, Anaconda, Mont. :—A dense quartz is preferable. The quartzite is the actual material used by the Anaconda Company. The sandstone referred to, the foreign quartz, was a very pure sandstone and had hardly any impurities in it, and the brick made from that particular material, while apparently beautiful while coming out of the kiln, and true, immediately on heating in the furnace buffed up half an inch and were cracked open.



## Assay for Gold and Silver by the Iron-Nail Method.

Discussion of the paper of E. J. Hall and C. W. Drury, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 78, June, 1913, pp. 1059 to 1066.

A. M. Smoot,\* New York, N. Y. (communication to the Secretary†):—The nails method is given in many text books on assaying as a standard method for gold or for gold and silver in ores. It appears to be taught in the laboratories of technical and scientific schools as a standard method, and to some extent it is used by assayers in actual practice, although the class of ores to which it may be applied is limited to those free from reducible metallic compounds, the metals of which would enter the lead button.

The experiments of Messrs. Hall and Drury show the inaccuracy of this method for silver, in heavy sulphides, but not so clearly the shortcomings with regard to gold. It seems certain that low silver is caused by the solubility of silver in iron-alkali sulphide as compared with its solubility in molten lead; that is, silver is distributed between iron-alkali sulphide and metal in the charge in proportion to solubility at the particular temperature of the fusion. Lead is a fixed quantity in these assay charges, but iron-alkali sulphide increases with increased sulphur, so the more sulphur in the charge, the lower the silver results.

Considering tests 1A and 2A, in Table I, it will be seen that the amount of pyrite in these charges was so small as to be fully oxidized by the litharge; consequently, the only sulphide sulphur likely to be in the slag would be produced from the reducing action of iron on sodium sulphate. Analyses of the slag show the sulphide sulphur to be very small, practically negligible in these charges. Both silver and gold results are substantially correct, gold being fully as high as in any of the niter-excess litharge charges (tests C), and silver, although a little lower, yet within the limits of ordinary assay errors. When sulphur in the charge increases beyond the amount which can be oxidized by 25 g. of litharge the silver figures drop proportionally to the increase in sulphur. It is quite evident that no iron at all was necessary in 2A, and that in 1A it was only necessary as a reducing agent to produce a proper sized lead button. In this charge a little carbonaceous reducing agent—say a gram of argol—could advantageously have been substituted for nails. The 1A and 2A charges are

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\* Chief Chemist, Ledoux & Co.

† Received July 21, 1913.

substantially excess-litharge charges, the slags being of the order of bisilicates. In all the other A charges, 3, 4, 5, 6, and 7, wherein pyrite exceeds the amount that can be oxidized by 25 g. of litharge, silver is markedly and increasingly low as the sulphur increases, and gold is also low, but by a practically fixed amount, averaging, say, 0.20 mg.

In the B experiments, wherein a large excess of argol was used, the silver results are of the same order as in the A experiments, going uniformly lower as the sulphide sulphur increases. The gold results, however, are different; charges 1B and 2B, containing only small amounts of pyrite, yield markedly low gold, whereas, omitting 4B, from which some lead was lost, the other B charges are only slightly low. It seems that, unlike silver, gold is not soluble in alkali-iron sulphide. A reasonable explanation for the low gold in 1B and 2B might be found in the nature of the slag. This is nearer a bisilicate than a monosilicate because of the large amount of silica added to make the weight of the "ore" equal to 0.5 A. T. Thus in 1A and 1B, 13.5 g. of silica were added; in 2A and 2B, 12.5 g. In these charges there is, therefore, no excess of soda to form iron-alkali sulphides, but as the pyrite is increased and the silica correspondingly decreased the charges become more basic, with higher results in gold in the case of the B experiments. It should be kept in mind that in the A charges no extra reducing agent is present, the slag is unsatisfactory, and the ore is probably not fully decomposed, while in the B charges argol is present in large excess. Probably in the B charges the litharge is reduced early in the fusion period, whereas in the A charges it is more slowly reduced by the sulphur in the ore. It is reasonable to suppose that the sulphide formed in 1B and 2B is really present as an iron matte disseminated through the slag, but not dissolved in the form of an iron-alkali sulphide, because there is no excess of alkali in these charges to form such a compound. As iron matte is an excellent solvent for gold, low results may be expected where it is formed.

In the case of the other B experiments, Nos. 3, 5, 6, and 7, where sulphur increases and silica decreases, presumably with the formation of alkali-iron sulphide in the slag, the gold figures are considerably higher than in the A experiments, subsequent to 3A.

This argument, based on Hall and Drury's experiments, points to the conclusion that the nails method would be improved for gold by increasing the alkali, so as always to form alkali-iron sulphide instead of iron matte, as well as by adding an excess of an organic reducing agent, thereby producing a better slag. Experimental evidence in

support of this suggestion is at present slender, but so far as it goes it supports the theory.

Two samples of heavy sulphide (pyritic) ores, assayed in Ledoux & Co.'s laboratory by the excess-litharge method, gave the following in ounces of gold per ton :

| Sample A.   | Sample B.   |
|-------------|-------------|
| 1.20        | 1.51        |
| 1.20        | 1.51        |
| 1.21        | 1.515       |
| <hr/> 1.203 | <hr/> 1.512 |

The same sample by the nails method, using the conventional charge of 0.5 A. T. ore, 30 g. sodium carbonate, 10 g. borax glass, 25 g. litharge, and 4 nails, gave :

| Sample A.  | Sample B.   |
|------------|-------------|
| 1.16       | 1.45        |
| 1.16       | 1.39        |
| .....      | 1.46        |
| <hr/> 1.16 | <hr/> 1.433 |

These results fully confirm prior experience, that the nails method, as ordinarily conducted, gives low gold. The nails method, modified by adding 5 g. of argol to the preceding charge and increasing the sodium carbonate to 60 g., gave :

| Sample A.  | Sample B.  |
|------------|------------|
| 1.22       | 1.50       |
| 1.24       | 1.50       |
| <hr/> 1.23 | <hr/> 1.50 |

It will be seen from the above that while the usual "nails" charges give markedly low results, the modified "nails" charges are commensurate with the excess-litharge method.

W. J. SHARWOOD, Lead, S. D. (communication to the Secretary \*) :—It seems possible that one of the principal differences between nail-method slags and the slags formed in the ordinary lead assay, in addition to those mentioned by the authors, and perhaps the chief cause of the less satisfactory character of the former, may be the presence of a larger proportion of ferrous sulphide, or, as usually stated, of ferrous alkaline sulphide. This is due to the relative smallness of the usual lead charge and its commonly lower proportion of sulphur.

Thus, with the ordinary 5-g. lead assay charge, a sample of pure galena would carry only 0.67 g. of total sulphur. With an ore consisting of one-third each of galena, blende, and pyrite, there would be 1.66 g. of sulphur. The proportion of alkaline flux per unit of ore, calculated to  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$ , is commonly somewhat greater in the lead assay than in the mixture used by the authors, and the large ratio of potash to soda also makes it decidedly more fusible than an unmixed soda flux.

The valuable data in Table I confirm what is, I believe, the general experience of assayers, that the nail method tends to give decidedly low silver results, but is reasonably accurate in regard to gold; while the niter fusion, if carefully performed, is fairly satisfactory for both gold and silver. The silver losses reported in this table for the nail method seem, however, unusually large.

Thus, in the four most highly sulphuretted charges (40 to 90 per cent. pure pyrite) the silver results, using nails and argol together, average 14 per cent. below the truth. Without argol the two highest in pyrite give errors of nearly 10 per cent., while with 40 and 60 per cent. of pyrite the silver is about 4 per cent. too low. On the other hand, the gold tends to be slightly higher with increasing pyrite—a result which might be modified were a large number of determinations made and averaged. The average gold value given in the table for the nail method is very nearly that of the uncorrected assay without pyrite. Is it possible that there is a trace of gold in the pyrite used?

The authors unfortunately do not mention the amounts of iron and lead in the slags, nor the size of the lead button obtained; presumably nearly all the lead was reduced. In the accompanying table I have taken the liberty of assuming, as an approximation based on the authors' data (p. 1064), that 14 g. of iron was removed from the nails in each of the tests numbered 5 and 7, and that 5 g. of lead remained in the slag. The tabulated molecular ratios indicate the nature of the slags obtained, from a chemical standpoint, perhaps more clearly than the mere percentage analysis. Even if as much as 5 g. of lead remains in the slag, it is evidently of relatively small importance compared with the other constituents, mostly of low molecular weight.

In some assays made several years ago, with charges of 0.5 and 1 assay ton of Frue concentrates containing up to 50 per cent. of pyrite and pyrrhotite, using nails or iron filings, a few slags were analyzed, and it was found that nearly half the sulphur remained in the slag as sulphide. It is interesting to note that the same is true of the high pyrite charges tabulated in this paper.

The size of the nails employed in these experiments is not stated. This seems to be a matter of some importance. Frequently a 20d. (4-in.) nail is used, either wire or cut. The late Richard Smith, when teaching assaying at the Royal School of Mines, used to recommend the cut nails then in vogue, used head downward to expose the greatest surface possible; alternatives being lengths of nail rod or pieces of 0.5-in. hoop iron, sometimes bent U-shape; or substituting a suitable amount of iron filings or turnings.

The manipulation necessary when large nails or long pieces of metal are used and removed, is a time-consuming inconvenience, while the waste of metal is considerable, as it is rarely safe to use a nail more than once. It seems desirable, therefore, to use iron in some form exposing more surface, adjusting the amount to the requirements of the case, so that all may be consumed, leaving no excess to be removed.

The idea is not a new one. In the case of the sulphide ores of lead, which are partly decomposable by sodium carbonate alone, partly by iron alone, but completely by both together, the use of iron filings is mentioned by Mitchell and by Percy, both of whom refer to still earlier work. In fact, this seems to have been one of the earliest forms in which iron was used for assay purposes. In Cramer's work on assaying (Mortimer's translation, 2d ed., 1764) one section is devoted to "Precipitation by Iron and Lead of Silver out of a Mixture containing a great Deal of Sulphur," in which the reader is cautioned "You must not use Filings quite spoiled with Rust: For they have no Virtue for absorbing the Sulphur."

At the Homestake assay office the practice, introduced about 10 years ago, is to use small steel wire nails, a number of which, suited to the material to be assayed, are stuck in the top of the charge before adding the borax cover. A size found well adapted to charges of tailing carrying from 3 to 5 per cent. of sulphur is a  $\frac{1}{8}$ -in. brad of 18-gauge wire, the diameter of which is about 0.045 in. An old Californian book—Barstow's *Sulphurets*, I believe—recommended small tacks for this purpose.

The authors evidently realize the advantage of using normal sodium carbonate (soda ash) as a flux, rather than the bicarbonate to which, for some unexplained reason, so many assayers still adhere. It may be worth while to point out here that soda ash usually costs less per pound, and that a pound of it contains over 50 per cent. more actual fluxing material than a pound of bicarbonate, though the latter gives off about 90 per cent. more gas per pound before action ceases. For every gram of  $\text{Na}_2\text{O}$  available as flux, one must use 1.7 g. dry sodium

*Computations from Data of Assays by Iron-Nail Method (Hall and Drury).*

| Charge. |       | S in FeS <sub>2</sub> . Gm. | Fe in FeS <sub>2</sub> . Gm. | Fe from Nails. Gm. | Total Iron. Gm. | SiO <sub>2</sub> . Gm. <sup>a</sup> | K <sub>2</sub> O from Argol. Gm. | Na <sub>2</sub> O from Na <sub>2</sub> CO <sub>3</sub> . Gm. | Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> . Gm. | Slag Constituents.  |        |         |                |                | Total Slag |                      | Actual Weight Slag. Gm. | PbO. Calc. 5 g. Left in Slag. Gm. |
|---------|-------|-----------------------------|------------------------------|--------------------|-----------------|-------------------------------------|----------------------------------|--------------------------------------------------------------|-----------------------------------------------------|---------------------|--------|---------|----------------|----------------|------------|----------------------|-------------------------|-----------------------------------|
| No.     | Grams |                             |                              |                    |                 |                                     |                                  |                                                              |                                                     | SO <sub>3</sub> Gm. | Sr Gm. | Sr' Gm. | Fe in FeS. Gm. | Fe in FeO. Gm. | PbO. Gm.   | Calc. Excl. PbO. Gm. |                         |                                   |
| 5A      | 14.6  | 4.55                        | 4                            | 14                 | 18              | 6.07                                | 0                                | 17.55                                                        | 10                                                  | 1.5                 | 8.75   | 2.57    | 4.5            | 13.54          | 17.4       | 61.84                | 52.8                    | 5                                 |
| 5B      | 14.6  | 4.55                        | 4                            | 14                 | 18              | 6.07                                | 1.25                             | 17.55                                                        | 10                                                  | 1.03                | 2.58   | 2.25    | 3.9            | 14.1           | 18.2       | 61.79                | 42.5                    | .....                             |
| 7A      | 14.6  | 6.86                        | 6.14                         | 14                 | 20.14           | 1.6                                 | 0                                | 17.55                                                        | 10                                                  | 0.82                | 2.06   | 3.43    | 6.0            | 14.14          | 18.2       | 58.83                | 62.4                    | .....                             |
| 7B      | 14.6  | 6.86                        | 6.14                         | 14                 | 20.14           | 1.6                                 | 1.25                             | 17.55                                                        | 10                                                  | 0.56                | 1.88   | 3.49    | 6.1            | 14.04          | 18.06      | 59.42                | 46.0                    | .....                             |
| 5A      |       |                             |                              |                    |                 | 100                                 | 0                                | 283                                                          | 50                                                  |                     | 47     |         | 80             |                | 240        |                      |                         | 22.5                              |
| 5B      |       |                             |                              |                    |                 | 100                                 | 13                               | 283                                                          | 50                                                  |                     | 32     |         | 70             |                | 252        |                      |                         | 22.5                              |
| 7A      |       |                             |                              |                    |                 | 28                                  | 0                                | 283                                                          | 50                                                  |                     | 25     |         | 107            |                | 252        |                      |                         | 22.5                              |
| 7B      |       |                             |                              |                    |                 | 28                                  | 13                               | 283                                                          | 50                                                  |                     | 17     |         | 109            |                | 250        |                      |                         | 22.5                              |

<sup>a</sup> Figures added to compute total slag weight. <sup>b</sup> Total weight, assuming all PbO reduced and CO<sub>2</sub> expelled, and neglecting corrosion of Pot.

*Molecular Ratios.*

|    | Na <sub>2</sub> SO <sub>4</sub> | Na <sub>2</sub> S. FeS. | K <sub>2</sub> O + Na <sub>2</sub> O Combined with SiO <sub>2</sub> , CO <sub>2</sub> , B <sub>2</sub> O <sub>3</sub> . | FeO. | SiO <sub>2</sub> . | B <sub>2</sub> O <sub>3</sub> . | PbO. |
|----|---------------------------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------|------|--------------------|---------------------------------|------|
| 5A | 47                              | 40                      | 246                                                                                                                     | 280  | 100                | 100                             | 22   |
| 5B | 32                              | 35                      | 289                                                                                                                     | 286  | 100                | 100                             | 22   |
| 7A | 25                              | 58                      | 255                                                                                                                     | 305  | 28                 | 100                             | 22   |
| 7B | 17                              | 55                      | 275                                                                                                                     | 302  | 28                 | 100                             | 22   |

carbonate (soda ash) or 2.7 g. of bicarbonate. If both are pure the volume of gas given off by the soda ash is just one-third of that evolved by an equivalent (not equal) weight of bicarbonate. Thus the amounts finally given off per gram of  $\text{Na}_2\text{O}$  available are nearly 500 and 1,500 cc. respectively if measured at  $100^\circ \text{C}$ ., or about double these volumes at  $400^\circ \text{C}$ .

The authors' data indicate the superiority of the niter assay to the nail method for high-sulphide ores, when silver is of importance. Some assayers, however, avoid large proportions of niter, on account of its tendency to boil over. Others do not hesitate to use 35 or g. more per charge, apparently without disastrous effects. This seems to be one of the instances where experience and close attention to details enable the successful use of a method which presents considerable difficulty to a novice.

A reagent which presents some advantages, and was recommended by Percy but is now little used, is red lead as a substitute for litharge. It contains at least 25 per cent. more oxygen, retaining it up to a fairly high temperature, so that the extra oxygen is available for the oxidation of sulphur or other reducing agents. Some of the redder samples of litharge in the market contain an appreciable amount of extra oxygen.

While it would not be permissible to make the slag highly acid in carrying out the nail assay, it seems desirable to add some silica whenever the percentage of pyrite is high, if only to check the corrosion of the crucibles. I believe this is common practice. One writer on assaying (W. L. Brown) has gone to the extreme of recommending the addition of silica to all assay charges—even with quartzose ores.

L. S. AUSTIN, Salt Lake City, Utah (communication to the Secretary \*):—Messrs. Hall and Drury have investigated the limitations of the nail assay under certain specified conditions, but one need not accordingly infer that it is to be set aside. It remains a quick and satisfactory method if judiciously used.

The nail assay has been long since tested out in practice, the results obtained by it having been compared with those from scorification and niter-fusion. This has been within the experience of many assayers, who, as the result of their long-continued experiences, have felt that they know how and when to use it.

The prospector frequently brings to the custom assayer samples of ore for assay, sometimes a single piece, sometimes an approximate sample of a face of ore, sometimes a "grab" sample, this latter a

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\* Received Sept. 9, 1913.

handful of ore taken at random from a heap, and mistakenly assumed by the taker to represent the heap. Under such circumstances a result a little low, as, for example, an ounce in twenty-five of silver, would be on the safe side, and would make no practical difference to the prospector. For the assay he wishes to pay, or can afford to pay, very little.

Again, a mine assayer may have dozens of assays to make daily, results from faces of stopes, grab samples from ore piles, from ore passing through the receiving bins and from other places, where approximations would serve every purpose.

In the paper several reasons are given in favor of the nail assay and these should have weight. These are: (1) That no preliminary treatment is needed, as in the niter assay. By this I understand the preliminary assay for reducing power, though I find that the skilled assayer, by doing a little panning of the ore or simply by inspection, can, four times out of five, determine the niter which should be added. The object of the preliminary work is of course (2) to insure a lead button for cupelling of the proper size. As to the third point, the method is economical. If the economy is in saving supplies, this should not influence one, but if time is economized, then such economy is another and an important consideration.

Certainly, as stated, the nail assay is hardly suited to ores containing appreciable quantities of impurities: viz., copper, arsenic, antimony, or tellurium. Such an ore would yield a hard button and this would have to be scorified, thus introducing double work, which it is the object of the nail assay to avoid. While this might indeed happen even to an experienced assayer, still it need seldom occur, and he could well afford to take the risk.

If the charges are properly made up, I am hardly prepared to agree with the authors that the slags are unsatisfactory in the larger number of fusions. As to low results with silver, we know that results are lower than by the niter assay, and when ore lots are assayed this latter method is indicated. In such cases, however, the assayer must use his best efforts, and spare neither time nor pains to insure the proper result. One experienced assayer, using the nail assay, asserts that the difference between it and the niter assay should not exceed 0.5 per cent.

The scorification method, formerly so much used, appears of late years to have dropped more out of sight. For all that, it is a most excellent method, and as a control on the crucible assay it may be used to great advantage, especially in the case of impure ores.

Since the nail assay is so convenient, so simple, and so inexpensive,



why not use it, preparing for it a charge which can be rapidly measured out? Such a charge might be thus specified:

|                      |                |
|----------------------|----------------|
| Ore .....            | 0.5 assay ton. |
| Soda.....            | 25 to 35 g.    |
| Litharge.....        | 20 g. or less. |
| Argol.....           | 3 to 4 g.      |
| Borax glass.....     | 5 to 15 g.     |
| Quartz sand.....     | 0 to 10 g.     |
| Ten-penny nails..... | 1 to 6.        |

Considering these fluxes in order:

For most ores 25 g. of soda is enough, but if the ore is nearly all silica 35 g. is needed. When the ore contains but little silica the deficiency is made up by the addition of sand up to the amount of 10 g., knowing that any shortage will be made up from the crucible itself. Glass may be used in place of sand, but to twice the quantity of the latter. I may say that for rather siliceous ores the crucible corrosion is not serious, but one is naturally desirous of saving the crucibles for other assays, and here again one must be cautious never to use it again on ores or ore lots when the results must be exact.

Twenty grams of litharge, which will be entirely reduced by the argols, gives a suitable-sized button, and it is not intended that any lead shall be left in the slag. In case the ore contains lead then the litharge is lessened to insure 18 g. of a button.

The quantity of argol is so small that its presence hardly affects the slag. Added to insure the reduction of all the lead in an oxidized ore, it is left standing even when not needed.

One can hardly use less than 5 g. of borax glass and be sure that the top of the charge is covered to exclude the air; 15 g. is added where the ore is decidedly basic.

The nails will vary, according to the judgment of the assayer. Though in an apparently oxidized ore the nails could be omitted, still one is retained as a precaution.

I will give now some examples of fluxing, applying the above principles, and using 0.5 assay ton of ore.

1. A quite siliceous ore with little base: Soda, 25 g.; litharge, 20 g.; argol, 3 g.; borax glass, 5 g.; and one nail.

2. An ore largely galena: Soda, 25 g.; litharge, 10 g.; argol, 3 g.; borax glass, 5 g.; and two nails.

3. A basic, oxidized ore with little or no lead: Soda, 25 g.; litharge, 20 g.; argol, 4 g.; borax glass, 15 g.; sand, 10 g.; and one nail.

4. A basic, blendy ore having little lead: Soda, 25 g.; litharge, 20 g.; argol, 3 g.; borax glass, 15 g.; with three nails.

5. An ore high in pyrite and having little silica: Soda, 25 g.; litharge, 20 g.; argol, 3 g.; borax glass, 15 g.; sand, 10 g.; and six nails.

Where the work is run hot, with pieces of coke placed at the mouth of the muffle, one should have but little trouble from drops of lead sticking to the nails, and with but little oxidizing effect upon the charge.

In conclusion, I would say that I consider the nail assay to be a speedy and practical method of determining ores, especially those where fairly approximate results will serve; but for obtaining the best and most accurate returns, one should use the niter assay or scorification.

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### The Laws of Jointing.

Discussion of the paper of Blamey Stevens, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 79, July, 1913, pp. 1285 to 1303.

F. L. GRAMMER, Leesburg, Va. (communication to the Secretary\*):—

Mr. Stevens refers to an explanation of parallel jointing by W. O. Crosby, which I noted when reading one of his excellent text books.

It seemed to me earthquakes were not a satisfactory explanation, and I looked up several authorities; but I never realized how small the usual amplitudes were until Mr. Stevens presented his paper.

Several letters to the U. S. Geodetic Survey showed me there were very few records of tidal movements of earth crust in the United States. Altitude and latitude would be influencing factors; but this diurnal movement must exceed earthquake amplitudes, besides being more nearly universal. My inquiries brought the answer that the major directions of jointing had not been extensively tabulated.

If major directions of jointing were recorded—with notes as to angle with mountain chain, or North Star, and distance between joints, with nature of rock and maximum and minimum tidal upheaval—some interesting relations might be made manifest.

Perhaps European tidal movements of solid crust have been more closely studied and their influence on joint direction and frequency in different classes of rocks commented on.

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\* Received Aug. 8, 1913.

## Valuation of Coal Land.

Discussion \* of the paper of H. M. Chance, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 79, July, 1913, pp. 1315 to 1341.

GEORGE H. ASHLEY,† Washington, D. C.:—Mr. Chance's long practical experience in reporting on coal lands admirably fits him for a discussion of the value of such lands. On behalf of the government geologists, I wish to express my appreciation of Mr. Chance's friendly, constructive criticism of the government method of valuing coal land in the first part of his paper and, at the same time, to reply to some queries he makes.

All admit that coal has no "intrinsic" monetary value, in the sense that a pound of coal of certain chemical and physical characters is worth "intrinsically" so many cents or fractions of a cent. The term has, however, been found very useful as including those natural factors of coal value, among which are its position and location in the earth, that affect its sale price in contrast with the other cost elements involved in the labor and capital necessary in mining, preparing, transporting, and selling the coal (extrinsic factors). Mr. Chance, while recognizing the "dual origin of value," does not offer any better terms.

The Survey agrees with Mr. Chance in his definition of coal conservation, that it means the fuller utilization of the heat contents of the coal, and the more complete recovery of the coal from the ground. Coal land withdrawals have not been made to keep such lands off the market, but to prevent their acquisition as non-coal lands before they could be classified so as to be disposed of under the proper law. Nor has the pricing of the more valuable coal lands above the minimum been to raise money for the Reclamation Fund, to which the money goes, but primarily to discourage the alienation, for holding or speculation, of coal lands not intended or needed for development, and, secondarily, to secure to the people the "unearned increment," which they are certain in any case to be charged.

Remembering that government prices of coal average well under 1 c. per ton, which with interest, etc., will hardly come to more than from 1.5 to 2 c. per ton when mined, as compared with the other charges against coal, such as the freight rate, which may run from 50 c. to \$5 per ton or more, it is not quite clear how the government

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† Chairman, Coal Section, Land Classification Board.

prices are going to be a burden on the ultimate consumer, particularly when, considered as a whole, that money has been in the consumer's other pocket or at interest for him. What the consumer objects to are the charges representing unearned increment on the land, unearned interest on watered stock, if such exists, unearned railroad rates where they are excessively high, etc.

Mr. Chance questions a number of the principles adopted by the Survey as governing factors, which he quotes. In view of the writer's belief that the cost of coal lands should be refunded within the first 20 years of mining, regardless of the life of the mine, it would seem from Mr. Chance's table under "Value as affected by ownership," that the value of a ton of coal at the time of opening of the mine is at least one-half the royalty rate. How much that rate should again be cut to allow a margin of safety depends on the local conditions in each case. For the "developed tonnage," to use Mr. Chance's term, one-half would seem to be a fair margin. In the government pricing, a safety margin of four-fifths or more of the estimated value is allowed.

Mr. Chance's question of the statement that "The government valuations cannot take account of changes in competition, markets, transportation facilities, or freight rates, or other factors that affect the profit," suggests that the statement should be modified or explained. Undoubtedly the government could take account of those things, but to do so would involve an enormous increase in the cost, not only of the field investigations, but of the office work in valuing the lands, probably doubling the cost and, with the present meager funds at the Survey's disposal, doubling the time required for the classification and valuation of the coal lands. There is also another side to this question. Coal lands far from railroad transportation today have practically no commercial value except for holding. To be utilized they must be brought into touch with transportation facilities. To sell such lands at their present actual commercial value would mean transferring their holding from the government to private owners, who must hold them at a high rate of interest, as compared with the government, or it would mean subsidizing the builders of railroads to them. Coal lands near railroads are still too abundant to need any such subsidizing beyond the one-half price reduction now made for lands more than 15 miles from a railroad.

The last questions will be considered together:

"The depth to which any coal can be mined is assumed to be directly proportional (?) to the B. t. u. value of the coal and inversely proportional to the cost of mining (?) for different thickness. . . . The value of coal is inversely proportional (?) to the cost of mining (see table on page 84)."

The Survey has taken the same ground as Mr. Chance, that the value of coal depends on the profits. No profit, no value; double net profit, double value. The depth to which any coal can be mined is that depth where the increasing cost of extraction extinguishes the profit.

The table referred to (page 84, *Bulletin* No. 587, U. S. Geological Survey) considers only the relative value of the *same* coal of different thicknesses. If a coal has no value unless it can be mined at a profit, to compare two coals of different thicknesses it must be assumed that the thinner coal can be worked at a profit. If a 2-ft. bed of a certain coal can be mined at a profit just vanishing, what will the profit be on a 4-ft. bed of the same coal? Obviously just the difference in the cost of mining between a 4-ft. and a 2-ft. bed. For the selling price, freight rates, etc., being the same, the profits in working the 4-ft. bed under conditions otherwise similar to those of working the 2-ft. bed, will just equal the difference between the cost of working the two beds. If the conditions be such that the minimum thickness for any coal can just be worked without loss, it is found that the profit in working beds of greater thickness approximates an inverse proportion to the cost of mining.

Frankly the facts are these: The study of the cost of mining different thicknesses of the same coal had brought out clearly the great difference in the cost of mining thin coals. As between the same coal in adjoining mines, a difference of thickness would undoubtedly affect the profits and to that extent the value of the coal. Could any definite relation existing between the cost of mining as affected by the thickness be found that could be systematically used in valuing coal lands? The premise given above was the only one that offered any definite answer, and, while it may never be quite correct in comparing the value of two thicknesses of the same coal, it appears to give the closest average solution of all cases.

The preceding statement that the value of coal or the depth to which it can be mined is proportional to the B. t. u. value is more open to question. It is approximately true from the standpoint of use; that is, that a ton of 15,000-B. t. u. coal contains as many B. t. u.'s as 1.5 tons of 10,000-B. t. u. coal and therefore is worth 1.5 times as much. Actually the first coal is worth a little more than 1.5 times as much as the poorer because of added cost after delivery to the boiler-room of the lower-grade coal, due to increased labor of stoking and removal of ash, increased storage capacity needed, and possibly to furnace difficulties. This may make a difference of say one-tenth to one-half between the two coals. Such a difference, however, may

be largely offset by the greater ash content of the higher-grade coal. On the whole it is not far from right, considered from the standpoint of use where no smoke ordinances are involved, but only horse power per dollar of fuel cost.

More and more, large users of coal are studying their coal bills so that, as between two coals with the same losses through the grate bars and out of the chimney per B. t. u. and the same ratio of impurities, they will be rated as follows:  $A$  (cost of poorer coal per ton)  $\times$  (B. t. u. of better coal divided by B. t. u. of poorer coal)  $+$  excess cost of handling and storage  $= B$  (equivalent cost of better coal per ton). If  $B$ , as so computed, is less than the market price of the better coal delivered, the poorer coal will be used. If  $B$  is more, the better will be used.

Leaving out of consideration household, coking, and blacksmith coals, which have special enhancing values and are specially treated in the regulations governing the pricing of government coal lands, the study of coal profits the country over in relation to B. t. u. value is confusing rather than enlightening. In general, such a study shows that coals of all degrees of heat values are being mined and marketed and that all of the profits are not going to the operators in high-grade steam coals. The old law of supply and demand soon levels down any high profit points, so that it must be doubted if the producers of Pittsburg steam coal are getting any larger profit per ton than a large share of the producers of sub-bituminous coal in the West. If the various coals were all grouped together in a small field, equally distant from a common market, either only one at a time would be worked or, if more than one, the profits on the better coals (cost and impurities being the same) would be governed by the B. t. u. value. But under the conditions actually existing each coal has its own field, whose size and limits are determined by the ability of reduced cost of production and B. t. u. value to overcome transportation charges against competing coals in every direction. In this competition the better-grade coals have the advantage of wider markets, of being able to carry higher operating costs, of being able to meet higher freight rates to common markets, and of being minable at a profit against lower-grade coals in the same field. In the West it is not an infrequent condition to find coals of different ages and different qualities in the same sequence of rocks. So that, notwithstanding the general statements just made, even though all coals were to be ultimately mined at about the same close margin of profit, the better coals can enter the market sooner and are stronger to meet adverse conditions and, therefore, must be considered as having a higher

value. That difference in value probably would be better expressed in a relation to B. t. u. that gave greater increased value to the higher-grade coals than that yielded by the simple proportion to the B. t. u. value; such as, for example, that expressed by the formula: price per ton of any coal equals its B. t. u. value divided by  $(10,000 + (15,000 - \text{B. t. u. value}))$ ; but considering that the basing price per ton is the one element of the regulations that, more than any other, would be sought by the public and form the basis of judging the regulations as a whole, it seemed wisest to use the simplest relation possible, one that was readily intelligible without computations or uncertainty. In the case cited by Mr. Chance of a 6-ft. bed of 9,800-B. t. u. coal and a 4-ft. bed of 15,000-B. t. u. coal, it is more than probable that under present-day conditions, if the 9,800-B. t. u. coal is being mined at all, it is situated under such conditions that it sells f. o. b. mine at about the same profit as the 15,000-B. t. u. coal at its mine.

In conclusion, it is evident to any one who has studied this subject at all that it involves a great number of factors in which theory must constantly be checked by the facts of the industry and in which the primary need is still for the collection and assembling of facts. Each constructive paper, such as that by Mr. Chance, adds its quota to the solution of the problems involved. No attempt is made here to review the main part of his paper, which will need more careful study than was possible in the brief time allowed for preparing this review. Such study, it is hoped, will be given in the succeeding months, and I believe that I voice the sentiments of my colleagues in stating that the Geological Survey stands ready to modify at any time its procedure in valuing coal lands when convinced by presentation of facts that its methods are erroneous or can be improved.

HOWARD N. EAVENSON, Gary, W. Va. (communication to the Secretary \*):—Mr. Chance is undoubtedly correct in his statement of the essential factors in fixing the value of coal land, and also in his objection to the use of a fixed royalty value per ton in making the valuation, on account of the appreciation usually found in this value as time demonstrates the worth of any particular coal field. Against this may be stated the argument that custom has usually fixed the royalty value at an average figure for any particular field and that this amount should govern the final valuation, particularly where the work is done for taxation purposes. The custom, now being introduced in some new leases in the bituminous fields, of exacting as

royalty a percentage of the selling price of the coal, will eliminate the objection stated to the use of royalty value, as the average amount paid under the new arrangement will undoubtedly give an accurate measure of the value of the coal.

Where the royalty, the quantity of recoverable coal, and the average rate of shipments—say, for the past five years—are known, it seems to the writer that the value of the coal land is the average price which will be paid for it at the royalty given and in the time which will be required to remove it at the known rate of shipment. For a seam from which can be mined 1,300 tons per acre-foot, at a royalty of 10 c. per ton, there will be paid, the year the coal is mined, \$130 per acre-foot; if the life of the mine (the amount of recoverable coal divided by the average rate of shipment) is 40 years, the present worth of the price to be paid for the last acre-foot of coal mined, at 6 per cent., is  $\frac{\$130}{10.28} = \$12.64$ , and the average value of the coal in the mine is  $\frac{\$130 + \$12.64}{2} = \$71.32$  per acre-foot. The amount of coal

recovered per acre-foot may change, the life of the property may be decreased or increased as the rate of shipment varies, and the interest rate may vary with financial conditions, but the writer believes that this method, when used with the proper factors, will give results which will check very closely with the figures of actual sales.

The writer is in thorough accord with Mr. Chance in his remarks about the assumptions made by the U. S. Geological Survey *Bulletin* on the method used by the government in fixing the selling price of coal land. Competition from other districts has certainly much more to do with the value of coal land than has the cost of mining. As an instance of this, certain coal lands in Alabama and West Virginia may be cited. In both States the coal is to be mined by shafts of about the same depths, the thicknesses of the two seams are practically the same, the West Virginia coal is superior in quality to the Alabama coal, but the former is now considered of no commercial value, while expensive plants are being erected to mine the latter.

R. B. BRINSMADE, Puebla, Puebla, Mexico (communication to the Secretary \*):—I find myself differing materially on but few points with Mr. Chance in his comprehensive and scientific treatment of coal-land valuation. On p. 1317 he says:

“As it is thus clear that the consumer must repay to the coal oper-

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\* Received Oct. 14, 1913.



stor the price paid for the land, the sale of coal land at 'coal land prices' by the government becomes in fact merely a method of raising money by taxing the consumer."

This view, that a higher price for land means necessarily a higher-priced coal, disregards entirely the effect of marginal land on prices, which I explained in my discussion<sup>1</sup> of Dr. Raymond's recent paper as follows:

*The Essential Factors in Fixing Prices.*

The rent of land is essentially a residual product, obtained by subtracting wages and interest from the wealth output; and this is true because both labor and capital must be continually supported and renewed or they perish, while land is self-supporting and self-existent.

In each industry there exists "marginal" land; *i. e.*, land whose product leaves no residuum after wages and interest have been paid. This marginal land varies in quality with commercial activity, but it may be described as the leanest land that has to be worked to satisfy the current requirements of the market. Though supply and demand may name the temporary price of a commodity, its average price is fixed by the cost of reproduction on marginal land; hence under normal conditions rent cannot enter into price, for marginal land is rentless. Only in the cases where all available marginal land was monopolized by some owner, who would not allow it to be used at all without the payment of rent, would rent become a factor in determining price.<sup>2</sup>

The rent of mineral land is usually collected as royalty, and, since the government has calculated its new coal-land prices from the basis of royalty value,<sup>3</sup> it is evident from my above quotation that these new prices will not affect the consumer, but will simply mean that the government will retain part of the land value which has hitherto enriched the coal-land speculator.

If the former policy of practically donating our coal resources to the first comer had not been discontinued, all our remaining coal of any value (present or prospective) would soon have become private property. Then could easily have arisen in the West what has already happened in the East for anthracite and coking coal; *i. e.*, all available marginal land being cornered the price of the output would cease to be competitive (set by cost of reproduction on marginal land) and become monopolistic, or "what the traffic would bear."

<sup>1</sup> Our National Resources and Our Federal Government, *Bulletin* No. 77, May, 1913, pp. 971 to 978.

<sup>2</sup> See also J. E. Symes, *Political Economy*, chap. viii. Karl Marx, *Capital*, vol. iii., chap. 44.

<sup>3</sup> *Bulletin* No. 557, U. S. Geological Survey (1913).

The unearned increment that Mr. Chance discusses on p. 1318 does not ordinarily affect coal prices, since all true land rent or royalty is individually unearned and arises solely from productive or marketing advantages which valuable coal land possesses beyond those of marginal coal land. The enhanced prices secured for those coals whose marginal lands have been cornered permits, it is true, the collection of a correspondingly larger royalty by the land owner, but this extra monopolistic royalty is no more unearned than the original competitive royalty, the former merely increasing by business artifice the natural difference in productive advantages.

On p. 49 of *Bulletin* No. 537, U. S. Geological Survey, is the statement:

"It would be a long step backward to return to the early policy of using the public lands as a means of Federal revenue, and any lease law enacted should be so framed as to encourage development, prohibit speculation, and add nothing to the cost of the resource to the consumer."

This sentence seems self-contradictory, for any Federal land rent which did not absorb more than the natural competitive royalty on the coal output could not affect the consumer, whatever its aggregate addition to the revenue. Within this limit, the larger the land rent the less left for the speculator's share of the unearned increment and consequently the less hindrance to legitimate development by speculators.

It is an established canon of taxation that taxes on commodities increase their prices,<sup>4</sup> while it is only taxes on the residual factor in production or land rent that cannot be shifted to the consumer. Excluding artificial monopoly and under normal competitive conditions, the only individually-unearned increment is found in land rent. Being *individually* unearned, land rent must be earned *socially*, and as it fluctuates in quantity with industrial activity and the consequent necessary cost of government, it forms the natural source of public revenue for a democratic nation.<sup>5</sup>

Thus "the long step backward of using public lands as a means of Federal revenue" seems a return to sanity from the long nightmare of Federal indirect taxation on the consumer, which has been so largely responsible for the reckless extravagance of the Congress and for the creation of so many unearned fortunes for the recipients of Federal land bounties.

Personally, I deem the leasing system more desirable than the sale

<sup>4</sup> Lawson Purdy: *Local Taxation*. J. E. Symes: *Political Economy*, chap. xvi.

<sup>5</sup> Henry George: *Our Land and Land Policy*.

of Federal coal land even at the present enhanced values. Leasing is more favorable for the small operator, since it saves him any initial investment in land. It better conserves both life and natural resources, for it gives the government a closer control of the method of exploitation. Lastly, it gives ultimately a much larger Federal revenue, without affecting either consumer or working operator, as evidenced by the basis of land-value calculation on pp. 81 and 82 of *Bulletin* No. 537.

This royalty basis, of only 1 c. a ton for a 6-ft. vein of coal of 12,500 B.t.u., is stated to be but "one-tenth the assumed average royalty rate" for privately-owned coal. This is done "in order to give the prospective buyer an ample margin of safety." But is the government so hard up that it need thus sell for cash its coal resources at one-tenth of their leasehold value? The above "ample margin of safety" means undoubtedly, in many cases, an ample margin for speculative profit also. Lands requiring an expensive equipment can be leased in large areas and on long terms to protect the operator, while retaining for the nation their full rental value by arranging for royalty payments on a sliding scale, adjustable to future changes in productive and market conditions.

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### The Precipitation of Copper from the Mine Waters of the Butte District.

Discussion of the paper of J. C. Febles, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 79, July, 1913, pp. 1267 to 1283.

J. W. RICHARDS, South Bethlehem, Pa. :—In looking at these precipitating launders the idea has come to me that the iron could probably be kept much cleaner if there were laid on the bottom of the launders some sheet copper, with which the iron would be in contact, and as the solution passed over the tendency would be to precipitate the copper on the sheet copper and thus keep the iron cleaner than it is under present conditions. As soon as a piece of iron becomes coated with copper its surface becomes inactive, and the presence of a sheet of copper in electrical contact with the iron would tend to precipitate the copper on the sheet copper and to keep the iron clean.

## Hardinge Mills vs. Chilean Mills.

Discussion of the paper of Robert Franke, presented at the Butte meeting, August, 1913,  
and printed in *Bulletin* No. 79, July, 1913, pp. 1201 to 1208.

ARTHUR O. GATES, Lafayette, Ind. (communication to the Secretary\*):—In connection with the comparison of mechanical crushing efficiencies in Tables I and II of Mr. Franke's paper, I wish to suggest a somewhat simpler way of making this comparison, based upon what the writer has called the "crushing-surface diagram," as published by him in the *Engineering and Mining Journal* for May 24, 1913. Such a diagram, based on the data given in Table II, is submitted herewith, Fig. 1, cumulative percentages being plotted as abscissæ and reciprocals of diameters (theoretical mesh per inch) plotted as ordinates.

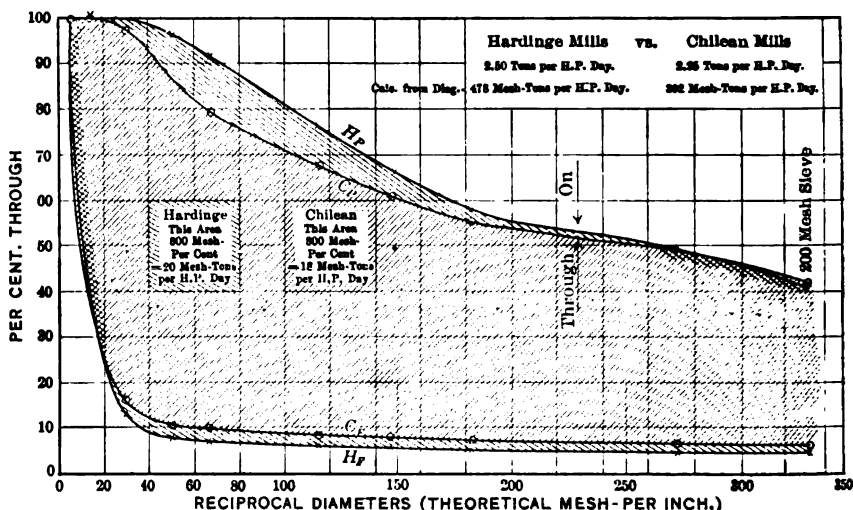


FIG. 1.—CRUSHING EFFICIENCIES OF HARDINGE AND CHILEAN MILLS, PLOTTED ON CRUSHING-SURFACE DIAGRAM.

calcs of diameters (theoretical mesh per inch) plotted as ordinates. Such a diagram averages the diameters without calculation, and areas upon it are proportional to surface produced, and, in accordance with Rittinger's law, to energy spent on crushing alone.

The Chilean mill diagram has been superimposed upon that of the Hardinge mill, the excess area of the latter measuring the excess of work done, based upon equal capacity. Measuring these areas up to 200 mesh (reciprocal 383), and multiplying by the tons per horse-

power day, the writer gets a production of 392 mesh-tons per horse-power day for the Chilean mill, and 478 mesh-tons per horse-power day for the Hardinge, an increase of some 22 per cent. in favor of the Hardinge. (The term *mesh-ton* represents the increased surface produced by crushing all particles of a ton of rock to a diameter whose reciprocal is one greater than in its previous condition. Diameter should be in inches, although of course this can be adapted to other units. For example, a ton of evenly sized pieces 1 in. in diameter would have 1 mesh-ton of surface; a ton of similar pieces just passing a hole 0.01 in., and retained on a screen with holes the reciprocal of whose diameter was 101, would have 100 mesh-tons of surface; the difference between two lots of 1 ton each, whose diameter reciprocals were respectively 99 and 100, is 1 mesh-ton.)

While the 22 per cent. in favor of the Hardinge mill checks with Mr. Franke's results, I wish to question his adoption of the value 400 as the reciprocal of average size of the material passing the 200-mesh sieve. From the way the curve of products is running (in the plotted crushing-surface diagram) there is every indication that there is 1,000 and 10,000 reciprocal (theoretical mesh) material present, so of course the average size is very much smaller than he has indicated. The field beyond 200 mesh (ordinary screen) has been so little explored that it would seem advisable to limit calculations on efficiencies to the plus 200-mesh sizes.

If the results of Mr. Franke's sizing analysis in Table II are plotted on logarithmic paper instead of on the crushing-surface diagram, the last few points will be found in a straight line for both machines, with this difference: the Hardinge line is steeper than the Chilean line, as shown in Fig. 2. I have found similar straight lines as a result of plotting other results, indicating a law by means of which the minus 200-mesh material may be studied. It will be sufficient to state here that the straight line indicates a hyperbola for the screen analysis plotted reciprocals against weights or percentages as in the crushing-surface diagram, and further, that the steeper line on the logarithmic plotting indicates the more efficient work.

In spite of the commercial success of the Hardinge mill, and the increased economic results accomplished by its introduction into concentrating mills, I wish to criticize the statements that, as in this paper, are so frequently made as to the value of the cone, its segregating action on the pulp, and the graduation of forces, intensities of energy, or inertia so that each particle gets just the right blow. I have never seen any published results of screen analyses of material taken at different points along the cone, and I do not think screen

analyses taken at these points will bear out the claims made for this feature.

Analyzing the mill on the assumption that the greatest diameter is to produce the greatest effect in crushing, we find that the weight of crushing pebbles is proportional to the square of the diameter (machine half full); that the energy per unit pebble weight is something

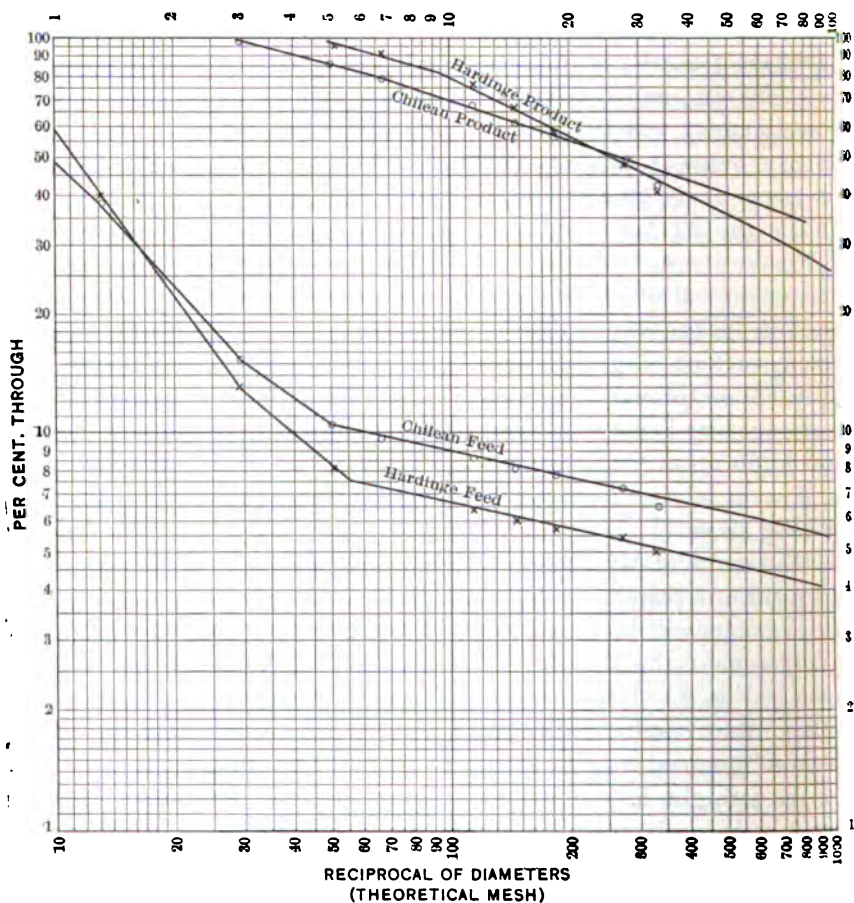


FIG. 2.—LOGARITHMIC PLOTTING OF CRUSHING EFFICIENCIES OF HARDINGE AND CHILEAN MILLS.

nearer the square than the first power of the diameter; and that the velocity with which the ore or pulp being crushed passes through the mill is inversely proportional to the square of the diameter. The result is that the energy applied per pound of pulp at various points along the cone is inversely proportional to about the sixth power of the diameter. This means that half way toward the apex of the cone, only 1/64 as much

work is done as at the cylindrical portion, while three-fourths of the way toward the apex, only  $1/4000$  is done. This means that the energy applied along the cone is so small that the force exerted by the falling or rolling pebbles is not sufficient to break the coarser particles, with the result that the work in the cone is largely done on the fines! This is as logical as the generally accepted explanation.

But the Hardinge mill is not run at such speeds that the effect of the large diameter is obtained; it runs at such a speed (750 ft. per

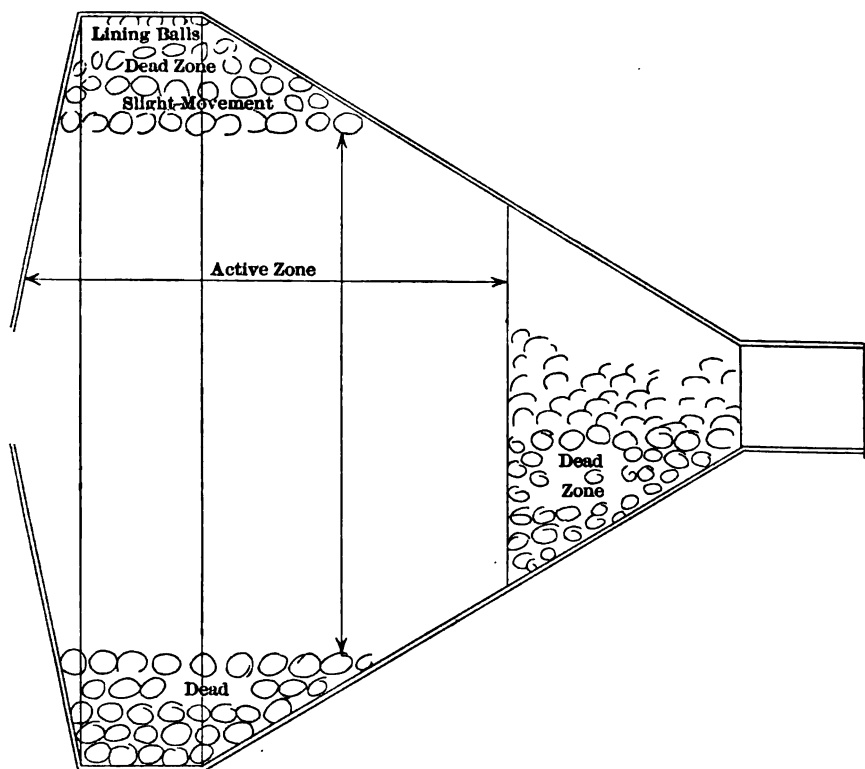


FIG. 3.—ACTIVE AND DEAD ZONES IN THE HARDINGE MILL.

minute peripheral speed or the 8-ft. diameter size, according to Mr. Hardinge<sup>1</sup>) that centrifugal force at the periphery is about 1.2 times that of gravity and therefore at least one layer of pebbles in the periphery is useless except for the purposes of lining. For at least a foot in, the possible fall of the pebbles is so slight as to be valueless for crushing. The result is, neglecting part of the apex of the cone where the energy is too small to be effective, the Hardinge mill

<sup>1</sup> *Bulletin No. 75, May, 1913, p. 460.*

resolves itself automatically into a short tube mill, the 8-ft. size producing about the same effect as a 5 by 5 or 6 by 6 ft. tube mill, as in Fig. 3.

Perhaps I am like the sailor's mother who could credit his story about the mermaids, but refused to believe what he told her about the flying fish. The segregation of the pebbles is entirely reasonable, the survival of the most energetic, but how can the fines separate them-

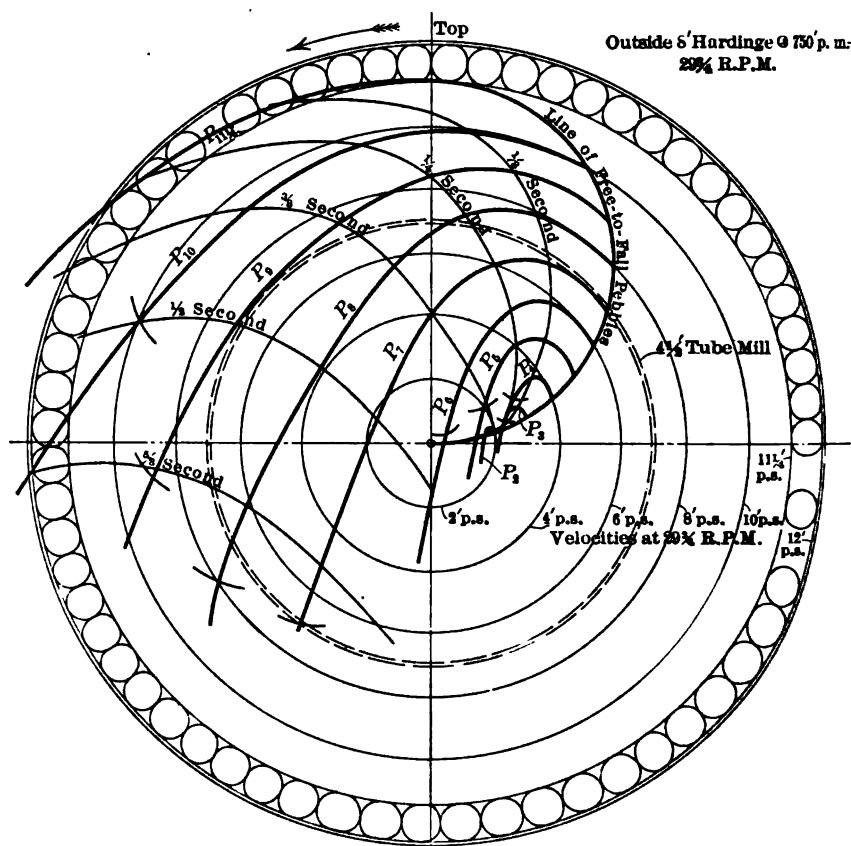


FIG. 4.—DIAGRAMMATIC REPRESENTATION OF THE ACTION IN A TUBE MILL.

selves from the coarse in the turmoil taking place within the crushing zone? The particle has got to go where it is knocked, the agitation is too great for it to follow any laws of classification, and it with the others passes through by displacement and chance, perhaps getting through without being hit at all; or again, a single particle in the final pulp may be the result of perhaps a hundred blows.

In Figs. 4 and 5 are plotted some graphical results of calculation of



what goes on inside a tube mill, particularly of the Hardinge type. The concentric circles in Fig. 4 represent planes through the cone. The velocity of each of these circles, based on 29.75 rev. per minute, is indicated in the lower right-hand quadrant. Applying the principles of mechanics, it will be found that pebbles will become free to fall when reaching the half-circle drawn in the upper right-hand quadrant, going up, and their paths from that time on will without interference follow the paths  $P_1$ ,  $P_2$ ,  $P_3$ , etc. Centrifugal force is too great on the outer ring of pebbles to let them move. Supposing pebbles to

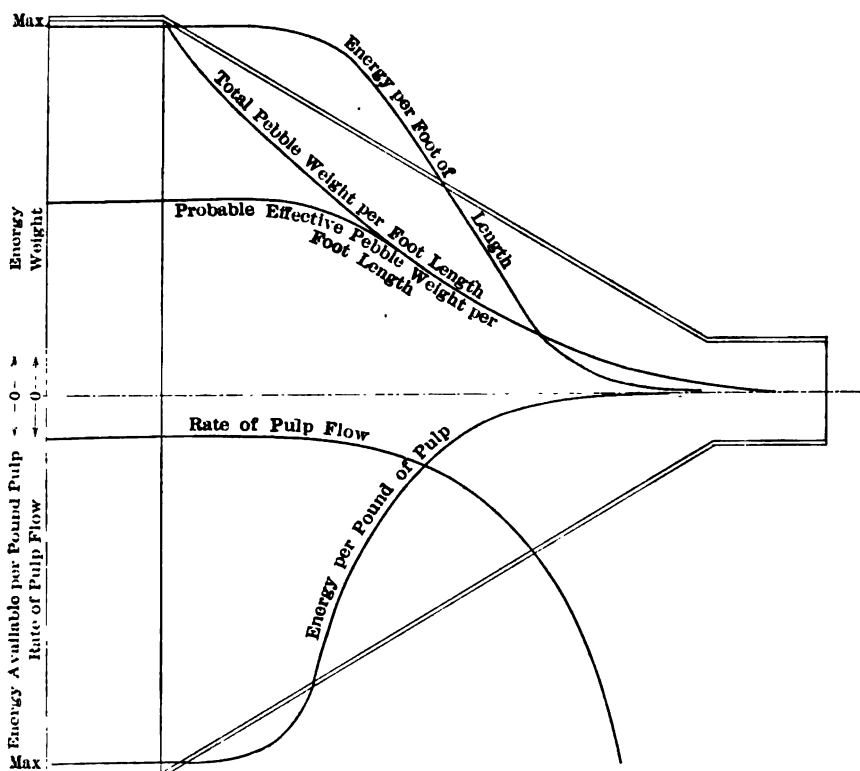


FIG. 5.—CURVES OF ENERGY, PEBBLE WEIGHT, AND FLOW OF PULP.

leave this half-circle along each of the concentric circles at the same time, lines of equal interval of time have been drawn so that one may judge velocities. I have not attempted to locate the landing place of the pebbles very accurately, although I have shown possible landing places by curved lines across the path lines. When these landing places are located properly the resultant velocity can be determined graphically, energy then being proportional to the square of the velocity.

In Fig. 5 are plotted away from the horizontal axis of the mill, weights and energy available per foot of length, for different positions along the length of the mill, and below, the rate of flow of pulp through the mill, and the energy per pound of pulp imparted by the action of the pebbles. The curves are plotted to relative units, not absolute.

I predict that the fine-crushing machine of the future concentrating mill will be a short tube mill, followed by an efficient sizer to remove more of the fine material than is done at present, and followed by a second short tube mill. And by short tube mill I mean short, 1 or 2 ft. long, and perhaps of large diameter, the pulp traveling through it rapidly so that the fines are not subjected to repeated crushing.

The great advantage of the Hardinge mill is in its simplicity, reliability, and low operating charges, as Mr. Franke has so clearly shown. and most operators are interested most in these features. His comparison of efficiencies is one of the first real quantitative comparisons made in this country. It is my opinion that the day is coming when such comparisons of efficiency will be made from day to day in our milling plants, just as in the power plant indicator cards are taken and worked up at frequent intervals.

### Notes on the Great Falls Electrolytic Plant.

Discussion of the paper of Willis T. Burns, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 2011 to 2049.

PROF. JOSEPH W. RICHARDS, South Bethlehem, Pa. :—I think Mr. Burns spoke of two unusual conditions which he has at his plant, namely, that he uses directly converter anodes and very high current density. He did not mention another condition: the very low cost of power, which circumstance, I believe, is responsible for some of the peculiarities of his plant noticed by us from the East. I am struck by the rather low ampere efficiency which Mr. Burns obtains, and in looking over the plant thought that there was a considerable leakage from one tank to the other, and that the ampere efficiency could be increased by looking after the leakage of electricity from one tank to the other.

## Roasting and Leaching Tailings at Anaconda, Mont.

Discussion of the paper of Frederick Laist, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 79, July, 1913, pp. 1147 to 1162.

J. C. DICK, Salt Lake City, Utah :—I would like to ask Mr. Laist why a 10 per cent. salt solution was used.

MR. LAIST :—The reason for using salt in the solution is to get the sulphur. The solution of dilute sulphuric acid has no solvent action on the sulphur even after roasting, and the addition of the salt is made primarily to dissolve the sulphur chlorides.

MR. DICK :—I would like to ask also if you made any experiments as to grinding fine your calcines, rather than leaving the coarse material.

MR. LAIST :—We have not made any experiments along those lines except in the laboratory, but the objections which we have to grinding are that the difficulties of roasting are very much greater when roasting finely ground material than when roasting coarse material, and the difficulties of leaching are somewhat increased; the percolating system is simpler and easier to manipulate, particularly when acid solutions are used, so that we prefer from our experience not to grind.

STUART CROASDALE,\* Denver, Colo. (communication to the Secretary †):—In order to meet the conditions involved in his ore-treatment problem, Mr. Laist has developed a very interesting and apparently successful metallurgical hybrid which he calls the oxychloridizing roast. The lower floors of the MacDougall furnaces are made to accomplish what used to be done on the "cooling floor" in the old days of salt roasting and "hypo" or brine leaching of silver ores.

His experience with the straight chloridizing roast recalls my own experience, of 10 to 15 years ago, while experimenting on the volatilization of metals as chlorides. I found that the highest loss by volatilization occurred when the salt and sulphur were present in quantities not only to combine theoretically with each other but also with the volatile base metal, like copper or lead, to form the normal sulphide and chloride of that metal. For example, an ore containing

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\* Non-member.

† Received Aug. 12, 1913.

2 per cent. of copper, if finely ground and roasted with 1 per cent. of sulphur and 4 per cent. of salt, would yield almost complete volatilization of the copper, while if roasted with the same amount of sulphur and 2 per cent. or 8 or 10 per cent. of salt the loss by volatilization would not be nearly as high. The same results would occur if the theoretical amount of salt was maintained and the quantity of sulphur was thrown out of proportion.

Carbonates, oxides, and silicates of copper could be readily chloridized and volatilized by the addition of sulphur as iron pyrite, and roasting with salt. Sulphide ores could be roasted "dead" and the copper could be volatilized by adding the theoretical quantity of salt and sulphur and again roasting at the proper temperature. Chalcocite and antimonial ores gave less loss by volatilization than chalcopyrite and the higher sulphides of copper.

Silver losses by volatilization are high if the volatile chlorides of the base metals are present, such as copper and lead. They are also much higher, at a given temperature, if an excess of air is admitted to the furnace and the ore is constantly rabbled, than they are when a minimum amount of air is admitted, or the furnace is closed and little or no rabbling is done.

The volatilization of copper begins at a dull red heat, or about 1,200° F.—perhaps below this point.

In a chloridizing roast, however, the dust losses cease as soon as chemical action begins, which is in the neighborhood of 1,000° F.

I experienced the same difficulty that Mr. Laist mentioned in trying to condense or collect copper chloride fumes when mixed with fire-box gases. These fumes seem to act much the same as zinc vapor under similar conditions. I drove the mixed gases into a condensing tower filled with fine gravel to a height of 8 ft. and covered with 3 in. of sand. This was sprayed with an excess of water. The copper chloride fumes came through it all, perfectly cold, but apparently untouched by the water. I have often thought that Dr. Cottrell might be able to collect them electrostatically when mixed with the products of combustion, but I have never tried it.

On the other hand, if these fumes are kept free from the products of combustion they are readily condensed by ordinary methods.

Mr. Laist brings out another point which I think is very important where roasting precedes the leaching of ore or tailings, and that is the formation of ferrites. This is particularly noticeable in roasting zinc ores.

I am somewhat surprised at the comparatively high acid consumption on his roasted material. I presume this is due to the ferrous and basic salts of iron formed by roasting at this temperature.

Carbonate ores with a granitic or porphyry gangue, that have been oxidized in place and in which no leaching has occurred, will contain considerable soluble iron and alumina. The iron will usually pass into solution as readily as the copper and the alumina soon follows, even in weak acid solutions. Since Mr. Laist employs an oxidizing roast as a preliminary operation, I believe he would find it advantageous to carry it to a higher stage of oxidation and render the iron and alumina more insoluble. This should not affect the chloridization of silver in any way.

The precipitation with hydrogen sulphide is an interesting development for the treatment of Anaconda tailings and we shall be glad to watch its continued use on a larger scale. At the present time precipitation is the most difficult part of the leaching problem to solve economically, especially on an Arizona desert, where the hydrometallurgy of copper is likely to reach its greatest development in this country.

W. McA. JOHNSON, Hartford, Conn. (communication to the Secretary\*):—I have read and re-read with pleasure Mr. Laist's paper on Roasting and Leaching Tailings at Anaconda, Mont. Mr. Laist's work has to my mind a distinct practical and commercial bearing on metallurgy and on the metal business, and so far as my powers allow me to I wish to consider briefly this phase of the subject.

Having been engaged for a considerable period in investigating new processes for separating copper-nickel matte for the old Orford Copper Co., and later having studied many processes for the treatment of zinc-lead ores, I have had, I believe, a certain sort of special experience in the development of new processes.

The valuable part of the knowledge derived from this experience can be summed up best as follows:

The ratio of the experimentally expended dollar to sum of the profits made from success, should it come, must be a maximum. In most cases, of course, this efficiency factor of the development of a new process is zero, for most attempts fail and in many successful cases the amount of money wasted is necessarily large. For instance, even Sir Henry Bessemer had to build 17 converters before his process and apparatus were practicalized. Now in the last analysis all this money apparently wasted in experimenting is a charge against the cost of making metal just as the money lost in prospecting and wasted in wild-cat mining ventures is a charge against the cost of making metal. Parenthetically let me state that in view of the industrial

\* Received Sept. 10, 1913.

absolutism of metal through modern civilization the price of metals does not average high enough when we consider the great amount of honest effort expended in finding mines, and new processes to make refractory ores available, and in the actual mining of the ore, smelting, and refining the metallic products thereof.

But in Mr. Laist's experimental work, as far as I can judge, a great deal of progress has been made simply as a result of frank discussion and of good counsel, and by the exercise of care and foresight; in short, a great deal of experimenting has been done by talking and on paper. For this reason I think that Mr. Laist's work is greatly to be commended.

Let us now consider his conclusion that the treatment of 3 per cent. concentrates is not advisable, but that the process is profitable and commercial on treating concentrates containing 0.5 per cent. of copper. This is, to my mind, in exact accord with a general broad principle of metallurgy that a series of processes or sub-processes, each performing its function at a maximum efficiency, makes the cheapest final operation and, of course, the cheapest metal. For instance, in roasting copper-nickel matte down from 22 per cent. of sulphur to 0.02 per cent. of sulphur from three to five operations are necessary, each one taking out the part of the sulphur for which the special operation is best fitted. A simpler example of this is the crushing of ores in several stages by crushers, rolls, and fine-grinding mills. If, therefore, we divest the question of its non-essentials and regard only the essentials we can see that Mr. Laist's process fits in the general metallurgy of Anaconda in a manner similar to the way that the cyanide process fits into the metallurgy of gold, where part of the gold is collected by mercury in the old-fashioned stamping process and where the product from the stamp mills is concentrated and the concentrates sold, and finally where the tailings are cyanided.

If Mr. Laist's proposal can be criticized at all it is that the capital cost of the demonstrating plant at Anaconda seems much higher than is really necessary and that the demonstrating plant is "over-designed." These are good faults in new work and such criticism can well be regarded as captious. If all the costs are figured on the same basis as \$4 for 60° B. sulphuric acid, out of 6 per cent. dust-free SO<sub>2</sub> gas, the financial returns will be gratifying, through chamber acid would be cheaper and as good. It also seems apparent that some continuous process for the leaching of the chloridized product must be finally used when the enormous tonnages that are rolling in at the Anaconda plant are treated. The means for precipitating the copper is, of course, susceptible of great improvement.

My regard for the work is high and my admiration genuine. Nor will any one adduce from this discussion of mine the argument that because the work has been done cheaply and efficiently copper should sell for less than 16 c. per pound.

R. C. CANBY, Miami, Ariz. (communication to the Secretary \*) :— Mr. Laist has shown the economic possibility of roasting and leaching at a figure which heretofore would have been considered an impossibility. Since having seen the conditions under which he roasted the 5,000 tons of tailings and having had the benefit of his personal description of his work, I have felt convinced that Mr. Laist and the Anaconda Company have inaugurated a new era in this branch of work.

A comparison of the temperatures of the different hearths of his No. 64 MacDougall roaster impressed me with the possibility of attaining even greater fuel economy by adopting the practice of Messrs. Sörenson and Barker<sup>1</sup>, and I have had in mind trying a furnace with the cast-iron hearths above the fired hearth, so as to gain the advantage of the convection of the heat, so that instead of a difference of 740° F. between the fired hearth and the one next above it, they should be more nearly equal. The manner of construction, with reinforced concrete for the fired hearths and hearths below, with less radiation from the walls than from the standard MacDougall furnace, would seem ideal.

There is one point which I hope will appear more fully in the discussion of Mr. Laist's paper, and of Mr. Wedge's paper read before the Boston Section, and that is as to how great is the advantage of the muffle type of furnace, which has seemed to me prohibitive in its fuel requirements. If the heat upon the approaching hearths were brought more nearly to 1,000° F., the fired hearth would undoubtedly require a less intense flame and there would be less danger of forming copper ferrite.

For using oil fuel upon such low-temperature roasts I propose a special burner for maintaining the ignition and economy of combustion, since in the Southwest oil is the more economical fuel.

Cast-iron flukes were used in cylindrical roasters at the Argentine plant, roasting 42 per cent. sulphur Congress concentrates for producing SO<sub>2</sub> gas for the Hunt and Douglas process, and I found cast iron gave better satisfaction than any other mode of construction.

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\* Received Aug. 16, 1913.

<sup>1</sup> *Engineering and Mining Journal*, vol. xcvi., No. 26, p. 1273 (June 28, 1913).

## Topographic Maps for the Mining Engineer.

Discussion of the paper of E. G. Woodruff, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 78, June, 1913, pp. 1001 to 1010.

F. A. LINFORTH, Butte, Mont. :—I have not had an opportunity of reading this paper thoroughly, but I would like to call attention to the possible use of the contours on fault planes. It is obvious that if the contours of fault surfaces can be determined, we will be able to determine the axes of the hollows in the fault surface. It seems probable, and there are examples to point to the accuracy of the assumption, that the axes of these hollows may be the direction of movements on the faults, and if that is true it will aid materially in locating faulted ore bodies or the shoots of ore on the opposite sides of faults. A few such contour maps of faults have been attempted on some of the faults of the Butte district, and those faults which are believed to have the nearly normal movement exhibit for the axes of these hollows a line nearly up and down in the plane of the fault, but in those cases where the throw is believed to be nearly horizontal we find that the axes of the hollows are almost horizontal lines. In other words, the movements on faults, I believe, would be more nearly indicated by the larger grooves in the fault surfaces than by the small slickensides and minor hollows that are seen, so that contour maps might be valuable in geology in that way.

C. W. GOODALE, Butte, Mont. :—I received a letter from Mr. Woodruff asking me to take part in the discussion of his paper, but I have not had time to give the paper any study. I can certainly add my opinion to that of all the engineers here that the topographic maps of the government are of great aid to the engineer. When I visit a new district, the first thing I do is to see if that district has been covered by the U. S. Geological Survey and if topographic map has been issued. And I find that some of the younger engineers frequently come into my office to see if I have such maps. I know in some cases the reports made out by engineers contain copies of these topographic maps, or clippings from them. I am sure that the topographic maps furnished by the government are of very great value to our engineers.

E. P. MATHEWSON, Anaconda, Mont. :—I would like to express my appreciation of these maps. Referring to a matter that is not strictly one to come before this audience: I had occasion recently to assist



in getting out a tour book for automobilists for the State of Montana. Montana is a big State; a great part of it is not surveyed, and we have not county maps for all the counties. The consequence is that many of our principal roads in the State of Montana are not marked on the maps, so we were at a loss to connect up some of the main highways on our tour maps, and the thought was suggested that possibly the topographic maps of the U. S. Geological Survey would help us. We immediately sought out topographic maps covering the districts in question, and to our great delight we found in most instances the county roads clearly marked, and they were entered on our tour books.

E. W. PARKER, Washington, D. C.:—I am not so familiar with the Topographic Branch of the Survey as I am with others, but we have with us to-day Mr. Manning, who is the Assistant Director of the Bureau of Mines, and I think he can explain something in regard to that if you can get him on his feet.

VAN. H. MANNING, Washington, D. C.:—I do not hesitate to get on my feet, but I know so much about the work of the Topographic Branch of the Geological Survey that I hardly know where to begin. I can, therefore, qualify to you as to my ability to speak authoritatively on this subject by saying I was a member of the Topographic Branch of the Geological Survey for over 20 years. However, I will start by replying to the inquiry as to why the U. S. Geological Survey has not been more liberal in the topographic mapping of the United States. The reason for this is because Congress has not made sufficient appropriations to survey a larger area.

I left the Geological Survey in 1910 and at that time there was about 33 per cent. of the total area of the United States surveyed. However, some of the topographic surveys covering this area were not up to the present standard of efficiency. Commenting upon the statement that has been made here of the accuracy of those topographic maps photographed up to a larger scale, I want to say that it is not always safe to make this enlargement by photography or by any other means, for such enlargements accentuate any error which is not appreciable on the smaller scale on which the map has been made. The maps should be revised about every 10 years, not because the topography will materially change, but for the purpose of adding the culture, such as roads, houses, etc., from time to time.

The Geological Survey is making better topographic maps to-day than it ever has before and the cost of making these maps is increas-

ing. In the early history of the Survey the cost of making these maps amounted to from \$2 to \$8 per square mile, and to-day it costs from \$20 upward for mining districts, the cost per square mile depending on the scale of the map and the character of the topography.

**MR. MATHEWSON:**—Is it not true that the Survey has given particular attention to the large mineral districts?

**MR. MANNING:**—Yes sir, and I may add, for the information of the mining engineers, the government has done away with the old contract system of land or rectangular surveys. Under the present system of having the work done by employees of the government working upon an annual salary basis these surveys are accurate and all fraudulent errors are thereby eliminated.

During my connection with the Geological Survey, I worked for a great many years in the public land States, and the locating of section corners set by contracts was in many areas a difficult thing to do. It was not always that I could find that a mile was a mile square. We of the Geological Survey tried to help you all we could in locating these corners accurately on the topographic maps, but we could not always locate the corners. Sometimes we thought we had them in their relative position, but the corners had either been moved by somebody, or they had been improperly set by the surveyor. The policy of the government is to give you a good survey, and a proper co-ordination of the topographic surveys by the Geological Survey and the rectangular surveys by the United States Land Office will bring about an improved condition both in accuracy and in economy.

**JOHN GILLIE, Butte, Mont.:**—I would like to commend the Geological Survey for the great assistance it has rendered the mining engineers in the West. Having been located here for more than 33 years, I have seen the start of it, and have been acquainted with many of the men who actually made the surveys. Also, I found the Director of the Survey has always been anxious to co-operate with the engineers in the localities and accept their suggestions as to the importance of carrying on any particular piece of work first. For that reason we have been enabled in Montana to secure quite a lot of topographic work. The districts like Butte, Helena, Philipsburg, Boulder, and others have been quite important in a mining way at different times, and upon our joint request we have always found the Survey courteous, and they have carried on good work. Mr. Mathewson and Mr. Goodale are familiar with an instance that happened in my own private practice a number of years ago in regard to the lost

corners that Mr. Manning spoke of. A homestead locator, about 12 miles east of Butte, in Elk Park district, was desirous of knowing the location of his farm corners—his 160 acres. The public surveys in this locality were quite limited at that time, and it was often necessary, if you did not know the location of the corners, to go a long distance to start from in order to identify the particular section. Upon applying at the office we made an appointment, and I suggested that he look up a corner, the nearest one that he could find, that we could start from. He said: "I have always known that that would be useful, and I have a corner carefully established." So, in a few days I went out there by appointment, and upon unhitching the team I asked if he could show me the corner he had located, and he said "Yes," and he took me up to his cabin, and pulled down a 4 by 4 post which he had carefully stowed away in the rafters of his cabin and properly marked. I said, "I don't want the actual corner; where was the actual corner?" and he said it was down in the meadow there somewhere; that he did not know exactly where. That is the idea some of them have. A few days ago I was out in the Swan River country, in which the General Land Office is extending its surveys, and on the trail I passed about 10 or 15 pack horses loaded with the present type of corner that the government is now establishing in the heavy timber, where it is likely to be destroyed by fire. These are metal posts with turned ends, and after seeing them planted I am certainly very much in favor of the government carrying on its own survey work.

MORTIMER A. SEARS, Denver, Colo. (communication to the Secretary \*):—Mr. Woodruff's contribution calls to mind the excellent paper<sup>1</sup> on *The Application of Descriptive Geometry to Mining Problems*, by Joseph W. Roe. The latter paper shows in detail and by specific problems how topographic and structural contour maps may be used in practice.

The writer is in almost constant use of topographic sheets published by the U. S. Geological Survey, and has found them of the greatest value. However, these maps should be used with caution, owing to the fact that formerly they were referred to an astronomic base and not sectionalized. Therefore, because of the notoriously bad condition of the public land surveys, it is difficult to correlate a definite point on the map with a certain definite point on the ground, the tendency being to assume a regularity of network which is far from correct. At the present time the topographic sheets are based

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\* Received July 15, 1913.

<sup>1</sup> *Trans.*, xli, 512 to 533 (1910).

upon a survey no less correct, but the government corners are tied in as they are found, so that the maps are much more satisfactory for quick reference. Also, in finding one's way about in an unfamiliar region it is well to bear in mind that some of the maps were published so long ago that many of the roads shown have now fallen into disuse or have been washed away.

In figuring drainage area the topographic sheets furnish an accurate and speedy basis for computations, especially when a planimeter is used, and Mr. Woodruff has very properly laid considerable stress on this point.

In attempting to determine the line of outcrop where there are few exposures and where one must frequently rely upon the records of deep wells a vast amount of work may be eliminated through a proper use of the maps.

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### Shaft-Sinking Methods of Butte.

Discussion of the paper of Norman B. Braly, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 1881 to 1906.

GEORGE A. PACKARD, Butte, Mont.:—I would like to ask Mr. Braly if he has any information as to the relative efficiency of the sinking pump, using it as he refers to it, discharging the exhaust into the water column or otherwise.

MR. BRALY:—I have never gathered any information on that point. It is a question of getting the work done. In driving the shaft, using that method, we find it easier on the men and everything else. In the bottom of the shaft, if you exhaust back into your column, it is a quiet shaft. Another thing is the freezing: if you are sinking with air in your pump, you will find it is liable to freeze, and in that case as the air is still under compression it will not freeze the pump. The difference is very small if there is any. But, as might be expected, the pump is a little less efficient when exhausting the air into the column.

MR. PACKARD:—I suppose all of us know what a pump in the bottom of the shaft is. My experience has been, although I have no figures, that the capacity of a pump is quite considerably decreased if you are pumping, say, from a depth of 200 ft. through a No. 7 Knowles pump, when you exhaust the air into a column, but, on the other hand, it is also my impression that we can raise the water to a little greater distance. I would like to get some figures from somebody who has made actual tests.

## The Reducibility of Metallic Oxides as Affected by Heat Treatment.

Discussion of the paper of Woolsey McA. Johnson, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 79, July, 1913, pp. 1137 to 1145.

F. L. GRAMMER, Leesburg, Va. (communication to the Secretary \*):—Mr. Johnson's paper must interest by suggestion those connected with the "burning" of lime, the production of cement, and the smelting of iron.

All iron men know how quickly the impalpable purple ore of wet origin reduces compared to finely ground red hematites of approximately identical composition obtained from Lake lump ores.

Most housekeepers appreciate that the several forms of carbon—charcoal, coke, and anthracite, not to include graphite and diamond—have different temperatures of ignition. The temperature usually rises with the density and hardness.

Some of the scientific bureaus of the government might appropriately conduct some tests along lines suggested by Mr. Johnson's article. We are unable to say whether the topic lies within the spheres of activity of the Bureau of Mines, the Bureau of Soils (Agricultural Department), the Geological Survey, or the Bureau of Standards. The calcining qualities of limestone is a topic too wide for individual effort and is of wide enough interest to merit government or State activity. It is of interest, as aforesaid, to burners of lime, cement manufacturers, and smelters.

The chemical composition of a limestone does not tell all the story—if over 1-in. size lumps. The limestones of Annville and Myers-town, Pa., break at a tap; those on the Hudson above Poughkeepsie act like "nigger heads." The manager of lime kilns near Lake Champlain told me his fuel consumption was high compared to that at other points. Yet the Hudson and Annville stones were both of greatest purity, being rivaled by only the marble at Rutland, Vt., or some stones near Martinsburg, W. Va. A local kiln operator says the conglomerate or pudding limestones of Loudoun county, Va., act very differently in the kiln from the more normal limestone deposits nearby. The tilted and twisted bedding in the anthracite region tells the story of hard coal origin. We might therefore expect that the limestones of greater geological age or depth or metamorphism

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\* Received Aug. 9, 1913.

(which are usually those most suited for building and ballast) would be least easily calcined.

Heretofore these practical differences recognized by the man who swings the sledge have been shown chiefly in repair items on the crusher. They would be more properly expressed in temperatures and heat units. But the calcination should be complete to make the comparisons of value. Manganese ores lose their first 40 or 50 per cent. of oxygen more readily than iron ores, but the final elimination is accomplished by a much larger expenditure of heat.

Often hardness and specific gravity will afford adequate indices of the refractory qualities of ore and stone. Every one appreciates that hard and heavy magnetites (usually attributed to igneous origin) are more refractory than hematites of water origin.

In handling a highly sulphurous roasted magnetite I once noted that if low sulphur in pig iron were the chief aim the very pure soft Annville limestone was most acceptable, but when off casts were made the loss through buckshot was much greater than with a poorer bastard dolomite found in the neighborhood. This may not be pertinent, but I am not persuaded that the several per cent. of magnesia made the difference between the two fluxes.

Many of us have acted as though the sole satellites of such men as Barus, Arrhenius, Nernst, and Jones were the followers of electro-metallurgy and industrial chemistry. Physical chemistry concerns us also. The catalytic value of manganese in the fertilizing serviceability of phosphoric basic slags is an appropriate topic for our papers as well as for the *Transactions* of other societies. Perhaps we can later have other tests made as to effect of physical nature on chemical activity.

It is probable that a given temperature and pressure of blast is best suited to each of the several forms of carbon fuel—charcoal, coke, and anthracite, and this also would be a proper subject for government inquiry.

Certainly the electric furnace offers a means of accurate experiment unknown to Sir Lowthian Bell; possibly some of his conclusions would be altered.

The sample of fused lime mentioned by Mr. Johnson would seem to us to indicate that where heat consolidates and hardens, the second state of the substance is more obstinate to chemical change—such as wood to charcoal or coal to coke; but where heat disperses and opens, the second state of the substance is more amenable to change by later heat action, viz., ice melted to water, heating ore lumps to

make friable—expelling combined water and  $\text{CO}_2$ —making same more reducible.

H. O. HOFMAN, Boston, Mass. (communication to the Secretary\*) :—The formulated statement of the author that in the reduction of metallic oxides, the higher either of the reacting bodies is previously heated, the higher is the reduction temperature, will strike home with all who have considered the subject. The fact is one which seems familiar; it required, however, the evidence furnished to make it sure.

The data of Bell which the author quotes serve as a reminder of the experiments carried on by Laudig and Bachman in 1896,<sup>1</sup> in which they subjected various iron ores to the reducing action of the tunnel-head gas of an iron blast furnace at  $432^\circ \text{C}$ . and noted the reduction and carbon deposition.

Below are given the results of some experiments I carried out with an electric resistance furnace in connection with some other work, in order to obtain numerical data in regard to the reduction of a hard hematite by means of several gaseous reducing agents.

The furnace was a vertical alundum tube 2 in. in diameter and 10 in. long wound with excello wire and packed in magnesia inclosed in a sheet-iron pipe. In order to protect the alundum against slagging, the tube was lined with a thin sheet of copper. The bottom of the tube was closed by an inverted crucible with perforated bottom and the joint made tight with a litharge-glycerine cement; the top was covered with wire gauze. The furnace was approximately standardized by passing through the heating wire the amperes necessary for obtaining certain temperatures. In making the tests the ore was charged into the tube, the gas passed through, the necessary electric current turned on, maintained for the desired time, turned off, and the ore allowed to cool in the gas current. The treated ore was emptied on to paper by tilting the tube and drawing it back. This spread the ore in the form of a long strip, from which samples were taken for analysis from top, middle, and bottom.

The reducing agents used were:

*Marsh gas*, with approximately  $\text{CH}_4$ , 90; H, 8;  $\text{CO}_2$ , 2 per cent. vol.

*Carbon monoxide*, practically pure.

*Boston illuminating gas*. Average composition:  $\text{C}_2\text{H}_{2n}$ , 15.0;  $\text{CH}_4$ , 25.9; CO, 15.3; H, 27.9;  $\text{CO}_2$ , 2.9; N, 3.0 per cent. vol.

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\* Received Sept. 3, 1913.

<sup>1</sup> *Trans.*, xxvi, 269, 1061 (1896).

*Producer gas* of an industrial plant with approximately: CO, 25; H, 10; N, 65 per cent. vol.

The metallization of iron was determined by boiling a finely ground sample of ore with a definite amount of solution of blue vitriol of known concentration, filtering, and titrating the copper in the filtrate.

The results obtained are given in the accompanying Table I.

1. *Marsh gas* has practically no effect within a range of 680° and 1,000° C.; only one of the six tests made showed some metallization.

2. *Carbon monoxide* gave no metallic iron, as shortly after a test had been begun the carbon deposition became so vigorous that the passages between the ore particles were choked with soot, and the test had to be stopped. If the gas had been diluted with nitrogen, less carbon would have been deposited, and some of the iron oxide reduced to the metallic state.

3. *Boston illuminating gas* shows a reduction of oxide between 880° and 1,040° C., the two highest percentages of metallization being 57.81 and 64.61 per cent. The  $C_2H_{2n}$  is in part decomposed by heat setting free carbon; the ore, firm when charged, has become friable; the soot, carbon monoxide, and hydrogen have penetrated the ore more or less; finely divided metallic iron is disseminated through unreduced ore.

4. *Producer gas* showed reduction of oxide in all tests; here again the hard ore has become friable and permeated with soot and with powdery metallic iron in intimate contact with oxide.

The results show that the two active gaseous reducing agents, carbon monoxide and hydrogen, reduce only in part a hard hematite, as had been shown for carbon monoxide by Bell; and that, irrespective of the reversibility of the reaction, the progress of the reduction is not simply a function of temperature and time.



TABLE I.—*Reduction of Hard Hematite.*

| Reducing Gas.                | Per Cent. Iron<br>in<br>Untreated<br>Ore. | Time of Treat-<br>ment.<br>Hr. Min. | Current in<br>Amperes.               | Temperature<br>° C.                                                | Sample of Ore<br>in Furnace,<br>Taken From                                       | Per Cent. Iron<br>in Treated<br>Ore.                                 | Per Cent.<br>Metallic Iron<br>in Treated<br>Ore                        | Per Cent.<br>Metallization                                               |
|------------------------------|-------------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------------------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------|--------------------------------------------------------------------------|
|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
| Marsh gas.....               | 47.26                                     | {<br>5-25<br>5-55                   | 7.2<br><br>7.7                       | {<br>840<br>940<br>680<br>890<br>1,000<br>730                      | bottom<br>middle<br>top<br>bottom<br>middle<br>top                               | 48.44<br>47.07<br>46.71<br>47.17<br>48.26<br>47.04                   | none<br>none<br>none<br>5.74<br>none<br>none                           | none<br>none<br>12.16<br>none<br>none                                    |
|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
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|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
| Carbon monoxide.....         | 47.26                                     | {<br>2-25                           | 7.6                                  | {<br>880<br>990<br>720                                             | bottom<br>middle<br>top                                                          | 46.21<br>47.23<br>47.14                                              | trace<br>none<br>none                                                  | none<br>none<br>none                                                     |
|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
| Boston illuminating gas..... | 47.26                                     | {<br>8-0<br>8-25<br>9-10<br>9-0     | 4.7<br><br>7.6<br><br>8.0<br><br>3.1 | {<br>615<br>435<br>880<br>990<br>930<br>1,040<br>760<br>340<br>405 | middle<br>top<br>bottom<br>middle<br>bottom<br>middle<br>top<br>bottom<br>middle | 47.06<br>47.15<br>48.67<br>51.86<br>50.65<br>51.93<br>47.12<br>..... | none<br>none<br>31.45<br>8.81<br>8.84<br>30.02<br>none<br>none<br>none | none<br>none<br>64.61<br>16.99<br>17.45<br>57.81<br>none<br>none<br>none |
|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
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|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
| Producer gas.....            | 68.25                                     | {<br>7-0<br>8-0                     | 7.6<br><br>5.0                       | {<br>880<br>990<br>720<br>560<br>655<br>460                        | bottom<br>middle<br>top<br>bottom<br>middle<br>top                               | 72.96<br>73.64<br>73.71<br>67.80<br>67.35<br>68.08                   | 31.26<br>20.79<br>28.87<br>10.58<br>14.66<br>8.92                      | 42.84<br>28.24<br>39.17<br>16.61<br>21.45<br>18.10                       |
|                              |                                           |                                     |                                      |                                                                    |                                                                                  |                                                                      |                                                                        |                                                                          |
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(20-Mesh.)

## The Smelting of Copper Ores in the Electric Furnace.

Discussion of the paper of Dorsey A. Lyon and Robert M. Keeney, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 2117 to 2149.

C. D. WOODWARD, Butte, Mont.:—We constructed a small blast furnace, and used first carbon electrodes and an alternating current of about 50 to 75 volts. We were able to smelt the material which was fed to the furnace, but we did not carry on experiments far enough to see just exactly what the power consumption was and compare it with the amount of material treated. We found that the blast seemed to help materially in reducing our charge and cutting down our power consumption.

There were several other experiments tried at the time, and I do not call to mind now just what they were. We were trying to do away with the carbon electrode and replace it with an iron one, and it also seems to me we tried to use the ore for an electrode; but I believe that the electric furnace in the reducing end is simply a question of British thermal units per kilowatt-hour compared with British thermal units in a pound of coke. Now, if a pound of coke costs us 0.5 c. and a kilowatt-hour costs us in the neighborhood of 1.5 c., I think there is a big advantage in using coke instead of the electrical current for copper reducing.

We tried steam, and a number of other methods, to throw copper down, but it has been some time ago and I am not very familiar with them now. The outlook of the experiments did not seem to be very promising, and we took it more as a thermal problem than an electrical one.

PROF. JOSEPH W. RICHARDS, South Bethlehem, Pa.:—Mr. Woodward has spoken of the question as a thermal problem. I would call attention to the fact that electric furnaces usually utilize the heat of the electric current at from four to ten times the efficiency with which the heat generated by fuel is utilized; so it will not do simply to compare by thermal units generated. Your total thermal units may cost much less from coke than from electricity, yet you will find the electrically generated thermal units utilized in a properly designed furnace from three to ten times more efficiently than in the combustion furnace. You must make that allowance in comparing the cost of thermal units generated electrically and thermal units from coke.

With regard to the melting of copper concentrates, which Mr. Lyon has spoken of, I think it will be found advisable to use the resistance electric furnace for this purpose rather than the arc furnace or the induction furnace. The arc furnace is the one most in use for steel, and the one which Mr. Lyon used, but there you are troubled with the volatility of copper. I think many difficulties can be overcome if electro-metallurgists will design a proper resistance furnace for copper which utilizes only the resistance of the charge and uses no electrodes and no arc. By using no arc you get away from the high temperatures which cause volatilization, and using no electrodes you save money. I think the resistance furnace will be found the proper type for most electric copper furnaces.

DORSEY A. LYON:—In that connection I will say we operated the furnace as a resistance furnace; we never allowed it to strike an arc. I quite agree with you that where you have an electrode you have a local high temperature. If you notice the design given, the idea is to distribute the current as much as possible; to use large electrodes to avoid an arc. If you could design a furnace to have no electrodes it would be a great improvement. So far we have not been able to do that.

C. D. WOODWARD:—That brings to mind now that we did try a resistance furnace, and we used iron electrodes, and, as the resistance of our ore varied according to the temperature, the heat seemed to be uncontrollable in the furnace; that is, it would have required perhaps a regulating transformer in order to hold the furnace down to some heat that would not explode the machine after we got a certain temperature on it. The furnace seemed to have about the same characteristics as a Nernst lamp, and, as the sulphur was driven from the ores, the resistance seemed to decrease and the flow of current evaporated until either the temperature of the furnace became an incandescent one or the voltage had to be reduced and followed up pretty closely.

DORSEY A. LYON:—I think it has been quite well proved in the iron industry that you have to have an invariable motor control. We start with one voltage and control the voltage to get just what we desire on the furnace. If you try to use variable voltage you will have the trouble you mentioned.

W. McA. JOHNSON, Hartford, Conn. (communication to the Secretary \*):—The writer's experience has been confined recently to the electric smelting of complex zinc ores. These ores usually carry lead or copper as by-products. So his experience will possibly throw some light on the subject so ably and conservatively treated by Mr. Lyon and also treated in a manner calculated to advance the progress of the art of electric smelting.

The first feature that is startling is the extremely low copper values in the slags made at the Hartford plant of the Continuous Zinc Furnace Co. In the last 14 months there has been made there some 16.9 tons of slag. In our furnace there are two tap-holes, one for slag and another for copper matte and lead. Through the latter some foul slag is tapped. An average (not, however, a weighted average sample) sample of these 104 taps of slag analyzes 0.065 per cent. copper (electrolytic assay on 5 g.); 0.05 per cent. Pb (wet assay on 5 g.); 0.50 oz. Ag on 2 A. T.; 0.01 oz. Au on 4 A. T. Many of the individual analyses have been checked by outside chemists.

Furthermore, in June, 1913, we made an eight-day run on a charge analyzing 0.43 per cent. Cu and made a matte analyzing 5.33 per cent. Cu with slag analyzing 0.05 per cent. Cu.

The conditions for the removal of copper, whether held in slag as copper silicates by chemical action, dissolved as copper sulphide in the slag by an indefinite chemical action, or held mechanically as particles of matte in physical suspension, are well-nigh ideal and can be briefly summarized as follows:

(1) A thinly liquid superheated slag. Our slags will run at 1,100° to 1,200° C., but are tapped at 1,250° to 1,350° C.

(2) A quiet pool of slag continually titillated by the 60-per-second pulsation of the alternating current in a manner similar to the rapping of the assay crucible by the assayer. Our Mr. E. N. Morrill pointed out to the writer this point.

(3) The intense reduction of the smelting zone that is strong enough to reduce 600 to 1,000 lb. of zinc oxide per ton of charge.

Each of the three makes for a complete separation of the copper from slag, be it held there originally by either chemical or physical forces.

The above is all based on actual experience and on what actually has happened. But if we consider what possibly could happen, let us suppose that we have two copper mixes, one basic and one acid, and power at \$0.003 and soft coal at \$3 per ton.

Now run the basic mix through a basic-lined preheater fired with

\* Received Sept. 10, 1913.

soft coal and mechanically operated, and run the acid charge through an acid-lined preheater of the above description and charge this with 1 per cent. of coal into a furnace something like our Hartford furnace for smelting complex sulphides. With the exothermic reaction of  $\text{FeO}$  and  $\text{CaO}$  on the  $\text{SiO}_2$  and preheating to  $1,100^\circ \text{C}$ . and smelting at  $1,300^\circ$ , the power consumption per ton of charge would be less than 300 kw-hr. in a 400-kw. unit. The amount of electrode consumed would be certainly less than 5 lb. per ton of charge, and with an open-flame reverberatory the coal for preheating would not amount to more than 12.5 per cent. of the charge.

Allowing for increased values of copper, silver, and gold recovered and considering the wider range of slags possible, as far as my judgment goes such a procedure would have great commercial worth if operated along several possible lines, such as smelting fine ore. The use of an electric furnace as a settler for hot copper-furnace slags and making out of them possibly also a low-carbon pig iron presents certain promising potentialities.

F. L. CLERC, Estes Park, Colo. (communication to the Secretary \*):—Among a number of very interesting questions raised in this paper, the following, quoted almost literally, but not consecutively or in full, appeal to me as having a wider interest in connection with the pyrometallurgical concentration of metallic values in lean ores.

"Whether electric heat may be used to replace the heat which is derived from the combustion of coke in pyrite and semi-pyrite processes . . . would it be possible and commercially feasible to carry out these processes in an electric furnace using a blast, obtaining as much heat as possible from the oxidation of the sulphur and iron, and supplying by electric energy whatever additional heat might be needed?"

"In true pyritic smelting 'there is no heat to spare.' If, therefore, pyritic smelting be attempted in an electric blast furnace, it would be necessary to supply the heat from the electric current in such a manner as to insure there being enough heat at the focus to carry on the reactions at that point."

Thermo-electric processes are flexible, "for with the electric current it would be an easy matter to quickly increase or decrease the heat required for the successful operation of the furnace."

"This extra heat doubtless furnishes just the necessary aid to bridge the operation over some critical point."

The suggestion I would make is this: Why not apply the elec-

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\* Received Sept. 27, 1913.

trically generated heat to the blast, and in that manner insure there being enough heat at the focus to carry on the reactions at that point?

These reactions are exothermic, and the attainable temperature depends on the rapidity of the reactions, but the reagents must be heated before the reaction will start. I recommended this procedure more than a year ago, for the igneous concentration of the zinc in mixed sulphide ores. It appears to have many advantages.

The furnace would be freed from the encumbrance of electrodes passing through the arch, and no special form would be required. The electrical stoves would be replaceable units, independent of the furnace structure, and all electrical connections would be readily accessible. There is little difference of opinion about the effect of a superheated blast in pyritic smelting. Superheated is understood to mean hotter than ordinarily used in the same branch of metallurgy. Most of the variations to be observed in practice are due to local conditions. It may be cheaper to add a little coke and use cold air, and more of it, than to install stoves for heating the blast, or the charge may be too fusible for a high furnace.

The idea of heating the blast at the tuyeres is not a new one; it was developed by W. Lawrence Austin, in connection with pyritic smelting, a dozen or more years ago. He burned petroleum with an air jet, in a cast-iron bulb surrounding the air pipe leading to the tuyeres.

It would appear that an electric heating section could be inserted in each of these pipes, and that, in addition to the heat required for normal working, additional heat could be supplied as desired, to carry the furnace over some critical point, either by increasing the temperature or the volume of the blast, at the particular tuyere where it would do most good, or by keeping in reserve a more intense blow pipe for use in emergencies, to fill the rôle of the "fighting tuyere," which iron furnace masters found useful in the days before a uniform furnace charge was practicable.

## Preparation of Ore Containing Zinc for the Recovery of Other Metals Such as Silver, Gold, Copper, and Lead by the Elimination and Subsequent Recovery of the Zinc as a Chemically Pure Zinc Product.

Discussion of the paper of S. E. Bretherton, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 1481 to 1487.

S. E. BRETHERTON, San Francisco, Cal. :—Since preparing my paper, our chemist, F. L. Wilson, has been experimenting with Leadville, Colo., oxidized zinc ore and Leadville zinc sulphides containing lead, operating upon 40-lb. lots at a time. His results on Leadville sulphides are as follows: The raw ore contained a trace of gold, 5.04 oz. of silver, 19.1 per cent. of zinc, and 7.24 per cent. of lead. After roasting the ore contained a trace of gold, 5.72 oz. of silver, 0.75 per cent. of copper, 21.7 per cent. of zinc, and 8.29 per cent. of lead. The loss in weight by leaching was 38.8 per cent. The extraction was 42.8 per cent. of the copper, 80.6 per cent. of the zinc, 7.1 per cent. of the lead, 0.64 per cent. of the silver, and no gold. The little silver that is extracted would be thrown down with the copper when precipitating it from the zinc and both thrown back into the residue to be smelted. There would be no trouble in smelting the residue with nearly all the sulphur eliminated and containing less than 7 per cent. of zinc. On zinc carbonates containing silicates the results are not satisfactory.

H. O. HOFMAN, Boston, Mass. (communication to the Secretary\*) :—The paper by Mr. Bretherton upon the application of ammonia and carbonic acid to the recovery of zinc as oxide from roasted sulphide ore is of interest to me, as the first installation of the Schnabel process for the extraction of zinc from a mixture of zinc oxide, lead oxide (with some cupric oxide), and pellets of enriched lead, produced in steaming liquated zinc-silver-lead crust of the Parkes process, was made at Lautenthal, Harz mountains, where I was chemist. In that capacity I carried out numerous experiments on the Schnabel process, was active in the erecting of the plant, and later had charge of it. After the Lautenthal plant had been in operation for some time a similar one was built at Hoboken-les-Anvers, but both have been abandoned, as the wet process could not compete with the distillation of the liquated zinc-silver-lead crust, now used universally in the Parkes process.

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\* Received Aug. 15, 1913.

The experience of Mr. Bretherton in not being able to extract a satisfactory percentage of zinc from an ore which had been partly sintered during the preparatory roasting is not surprising, as it is one which is frequently encountered even when an ore has been only overheated. Mr. Laist called attention to this fact in his paper<sup>1</sup> on the lixiviation of concentration tailings at Anaconda.

The analysis of the material treated at Lautenthal as quoted by Schnabel<sup>2</sup> gives: Pb, 80.065; PbO, 36.87; Zn, 1.9; ZnO, 23.24; Cu, 1.24; Ag, 1.855; Bi<sub>2</sub>O<sub>3</sub>, 0.44; Sb<sub>2</sub>O<sub>3</sub>, 0.57; Fe<sub>2</sub>O<sub>3</sub>, 3.82 per cent. There is no siliceous gangue to cause sintering, hence the zinc oxide, after having been heated to a light cherry red, say 850° C., remained readily soluble in ammonium sesquicarbonate.

Some of the tests upon the solubility of zinc oxide in ammonia and ammonium sesquicarbonate which I carried out have been published by Schnabel<sup>3</sup>. I give them in Tables I and II, as they may be of service in the working out of the proposed process.

TABLE I.—*Solubility of Zinc Oxide in Solutions of Ammonia.*

|                                               |      |      |      |      |      |      |      |      |      |      |
|-----------------------------------------------|------|------|------|------|------|------|------|------|------|------|
| 100 g. solution with g. NH <sub>3</sub> ..... | 20   | 15   | 10   | 9    | 8    | 7    | 6    | 5    | 4    | 3    |
| Dissolve at 14° C. in 24 hr. g. ZnO.....      | 1.78 | 1.75 | 1.51 | 1.34 | 1.12 | 0.91 | 0.76 | 0.56 | 0.45 | 0.25 |

The solubility of zinc oxide in caustic ammonia is too small to be of any practical value.

TABLE II.—*Solubility of Zinc Oxide in Solutions of Ammonium Carbonate.*

| 100 g. Solvent Containing, g. |                 | Dissolve in 24 hr.<br>at Room<br>Temperature g.<br>ZnO. | 100 g. Solvent Containing, g. |                 | Dissolve in 24 hr.<br>at Room<br>Temperature g.<br>ZnO. |
|-------------------------------|-----------------|---------------------------------------------------------|-------------------------------|-----------------|---------------------------------------------------------|
| NH <sub>3</sub>               | CO <sub>2</sub> |                                                         | NH <sub>3</sub>               | CO <sub>2</sub> |                                                         |
| 6.49                          | 2.70            | 3.60                                                    | 6.17                          | 7.94            | 9.85                                                    |
| 6.44                          | 3.36            | 6.45                                                    | 6.13                          | 8.61            | 9.95                                                    |
| 6.34                          | 5.07            | 8.65                                                    | 6.05                          | 10.07           | 10.65                                                   |
| 6.25                          | 6.02            | 9.95                                                    | 6.03                          | 10.47           | 9.95                                                    |
| 6.28                          | 6.06            | 9.75                                                    | 5.91                          | 12.63           | 7.95                                                    |
| 6.19                          | 7.59            | 10.05                                                   | 5.90                          | 12.81           | 7.35                                                    |

The solutions were prepared by passing carbon dioxide through ammonia liquor with 6.664 per cent. of NH<sub>3</sub> for different periods of time; the CO<sub>2</sub> contents were then determined. The table shows that for 6 per cent. ammonia liquor the greatest dissolving power for zinc

<sup>1</sup> Bulletin No. 79, July, 1913, pp. 1147 to 1162.

<sup>2</sup> Schnabel, C.—Louis H.: *Handbook of Metallurgy*, vol. i, p. 677 (1905).

<sup>3</sup> *Zeitschrift für das Berg- Hütten- und Salinenwesen im preussischen Staate*, vol. xxviii, pp. 279 and 280 (1880).



oxide lies between 6 and 10 per cent.  $\text{CO}_2$ ; 1 g. of  $\text{NH}_3$  will dissolve about 1.5 g. of  $\text{ZnO}$ . Lengthening the time for solution from 24 to 36 hr. showed little increase in the amount of  $\text{ZnO}$  dissolved; raising the temperature to  $30^\circ \text{C}$ . had a more favorable effect. In the plant the standard solvent contained 9 per cent. of  $\text{NH}_3$  and 9 per cent. of  $\text{CO}_2$ .

The manner in which the Schnabel process was carried out at Lautenthal is described on pp. 679-680 of Schnabel's treatise already quoted.

The ore was leached in a horizontal boiler-iron drum with revolving shaft provided with arms. In fact, every apparatus in the mill was a closed iron vessel strong enough to withstand considerable pressure. The vessels were provided with bottom pipes and valves for liquors and similar devices for gases.

The leached residue was washed in a filter press, which was ammonia-tight, and was there freed from ammonia; whether a similar result will be obtained with an ore containing a gangue only practical experience can tell, as the gangue is liable to hold back ammonia more tenaciously than a mixture of lead, lead oxide, and zinc oxide. A large Merrill press can be made ammonia-tight, as was the small Dehne press used at Lautenthal.

The precipitation of the copper was easily accomplished, only care had to be taken to relieve the pressure of the hydrogen without wasting ammonia. With an ore not carrying metallic zinc this feature probably need not be considered. The removal and washing of the precipitated copper is another important factor.

The distillation of the ammonia-zinc solution freed from copper was a brilliant success, the liquor showing only a trace of ammonia.

The calcination of the basic carbonate in a muffle furnace was accompanied by difficulties, as at a certain temperature the powdery charge begins to run as soon as it is touched with a rabble. The recovery of the carbon dioxide from the basic zinc carbonate was given up at the plant, and fresh gas prepared from burning coke.

The process outlined by Mr. Bretherton has possibilities, but many difficulties of a mechanical nature will have to be overcome before it can become a commercial success. However, the handling of large quantities of material with ammonia in closed vessels, *e. g.*, in the Solvay process for the manufacture of sodium carbonate, is not uncommon at present, so that there is a prospect in the end of a favorable result.

## Timbering in the Butte Mines.

Discussion of the paper of B. H. Dunshee, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 1511 to 1531.

GEORGE E. MOULTHROP, Butte, Mont.:—The recording for the first time by Mr. Dunshee, in a readily usable form, of the various systems of square-set framing applied in the Butte district is a valuable contribution to mining information. The many different methods of framing employed, due to the individual ideas of superintendents and foremen of segregated companies, have given full opportunity to determine the best framing for the conditions as found in these mines, and the final adoption of a system uniform for all the mines has come about through a study of these various methods and an experience covering a period of many years.

The sawed 10 by 10 in. and 12 by 12 in. timbers undoubtedly give the best satisfaction; and the style of framing the sawed timber that under all conditions has given the best practical results is that used in the Anaconda group and other mines, described and recommended by Mr. Dunshee. In this framing the posts have a horn 2 in. high and 6 in. square, the cap end having dimensions of 3 by 6 in. Instead of the framed girt shown in the drawings of the Anaconda group, the 6 by 10 in. girt adopted at some other mines, which fits into the cap and post framing with no other preparation than cutting the timber to the necessary length, fills all the necessary requirements for strength and affects a material saving in timber and labor. This, as Mr. Dunshee states, is without doubt the type of framing which would be adopted as a standard for 10 by 10 in. sawed timbers if sawed timber sets were to be used in the future generally. But saw-timber for the mines was becoming scarce and expensive, and round timber for the square sets furnished an alternative which provided, at greatly reduced cost, material which in every way supplied the requirements of the mining conditions.

The use of the round timber with a satisfactory framing makes available a conveniently located and large source of supply which up to this time has served no useful industrial purpose. Particularly is this true of small timber, which is still standing in great quantities in the forests where the trees more desirable for commercial purposes have already been cut and marketed.

Then, too, timber which is damaged by fire and down-timber which is in a fair state of preservation can be framed for the mine sets and

used to as good advantage as the best fir timber in stopes which are filled with waste material almost as soon as the timbers are put in place by the miners.

Of the three forms of framing round timber which have been tried and used extensively in the mines, the present so-called step-down system is the only one which, after a year's trial, appears to give as much satisfaction as any framing used on 10 by 10 in. sawed timber. Mine foremen and miners use the sets framed after this pattern without opposition and the mines generally are visited with fewer caves than when the highest grade of sawed fir timber was plentiful and used exclusively.

The framing first adopted, in the so-called mitered sets with beveled surfaces, prior to the adoption of the square-cornered, step-down form of framing, failed completely in its practical application in the mines. This was due to the impossibility of blocking the sets rigidly enough to withstand the shock of ordinary blasting, and it took considerably more time to stand and block them even insecurely into position.

As the wall rock of many of the principal veins is never solid material, but to a greater or less degree mineralized granite which on exposure to air disintegrates and falls down from the walls, the most careful blocking of the sets of any style of framing is found in a short time to have dropped from place, the ground having fallen from behind the blocking. A slight weight of ground settling on the timbers had the effect of moving laterally the beveled posts and to such a degree that a cap or girt would fall out of its position, and when this happened, even if in only one set of a large stope of 50 or more sets, the concussion of a blast caused all the sets to fall to the floor of the stope. On this account, following the regular timbering gang, it was necessary to employ extra crews whose duty it was to examine and re-block the sets. On the other hand, with the square-corner framing the experience has been that with the falling out of the blocking of even several sets of a stope the weight of the ground takes effect more nearly vertically, and instead of the posts easily sliding laterally on the beveled surfaces, the weight binds the sets tightly together, and no amount of blasting ever sweeps down any great number of sets of a large stope, as was the common and usual case with the mitered sets.

More care and time are necessary in standing a set of round timbers than with the sawed timber sets, as with the latter it is an easy matter to stand a post in exact line with the sets already in place by sighting with the eye along the faces of the standing and blocked sets.

With the round timbers, which are always of varying sizes, this method is impossible, and the miner, after temporarily placing the several members of the set into their approximately correct positions, proceeds to block the set and by wedges brings the framed ends into a close and even fitting. The fitting of these unions is the indication of the accuracy of the square formed by the timbers. The measurement of the diagonals is a common and the best way of determining the correctness of the position of the set.

With the drift and sill-floor posts, which are flat-bottom, being framed at the top end only, the common practice is to first place as a sill a 2-in. plank, on the ends of which rest the posts. The position of the plank is determined by a carpenter's level or a grade-staff to obtain the correct elevation for the desired grade—0.25 to 0.5 in. per set—the alignment being determined by bringing the center of the plank to a point in line with two plumb lines hung from the centers of caps in sets already standing in the same row. Where ore chutes are to be built in, in the sets, and these are often as frequent as every 25 ft., 10 by 10 in. square timbers are used, instead of the round timbers, in order that a smooth surface may be had to which is spiked the 2 or 3 in. plank lining. These 10 by 10 in. square sets for the ore chutes are carried from one level to another as the stope progresses, so that every fifth or sixth set, instead of being of round timber, is of 10 by 10 in. timber framed like the round.

Round timber is sometimes hewed so that the chute lining may be spiked to it, but in heavy, moving ground the chute in square timber stands better and lasts longer.

## Ore Deposits at Butte, Mont.

Discussion of the paper of Reno H. Sales, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 1524 to 1626.

L. C. GRATON, Cambridge, Mass.:—It has been my privilege to read with some care Mr. Sales's paper, and I feel it a sense of duty and a pleasure to discuss it briefly. After two months spent underground in the Butte mines by my associates—Messrs. Augustus Locke, A. M. Bateman, and E. H. Perry—and myself, it seems only fair to record our appreciation of the almost baffling structural complexity of the Butte veins, of the remarkable accuracy with which their mechanical details have been worked out, and of the unusually effective and intelligent use of geologic conceptions in interpreting their subtler characters and significance. During this period, under the courteous and helpful guidance of either Mr. Sales, the members of his staff, or the geologists of other companies, we have been afforded opportunity to test many of the conclusions embodied in the present paper, and it is but just to state that as our observations have accumulated sufficiently the great majority of these conclusions have received unquestioned confirmation in our minds.

The pleasure consists in realization that the science of mining geology, to which so many of us have devoted ourselves, actually embraces the possibilities that this paper exhibits. The science of geology has been favored by many brilliant contributions of general nature, and by a smaller number of studies remarkable because of their detail and precision. I know, however, of no other piece of work like this, which, including Mr. Winchell's administration, virtually represents the combined results of over 15 years of work by a staff of trained geologists in a district which measures not much more from end to end than it now does from top to bottom. That this concentration of effort and observation has been required, and that it has been repaid by the results attained, are plentifully evident in Mr. Sales's paper. If one were inclined to doubt this after perusal of the text, surely he would be convinced by the maps and sections, several of which, I venture to say, are unapproached in detail and accuracy by anything attempted before.

Among the features of more general geologic significance mentioned by Mr. Sales that we have had opportunity to confirm to our own satisfaction may be noted the peculiar character of the Mountain

View fault breccia; the essential unity of the period of primary mineralization in the district, regardless of the trend or age of the fractures; and the rudely concentric zoning exhibited both by intensity of alteration and by character of ore minerals deposited.

The subject upon which Mr. Sales places most emphasis, viz., the origin of the deep-level chalcocite, is one that possesses far more than ordinary interest for the four of us who are beginning here a country-wide study of secondary enrichment of copper deposits. I may say that Mr. Sales and I are not wholly in accord regarding some features of chalcocite occurrence and significance at Butte, but as my own views are not fully shared by my associates, it would seem the better part of valor to postpone any statement upon this subject until more thorough study can be given to it. That this problem is extremely complex will probably be admitted by all acquainted with it. In any event, after microscopic study of nearly a thousand specimens of Butte ores, we are fully agreed with Mr. Sales that there are great quantities of original or primary chalcocite in these ores, and that several other rich copper minerals so plentiful here, notably enargite and bornite, are predominantly primary and not due in any important degree to influences active at or near the surface.

It appears, therefore, as pointed out elsewhere,<sup>1</sup> that the history of this greatest of the world's copper camps is not soon to be ingloriously terminated by a giving out of downward enrichment, but instead that, regardless of whatever alterations may have affected the deeper ores now known, profitable mining will probably be able to continue as far as the physical limitations of depth and vagaries of primary ore deposition will permit.

One might have wished that Mr. Sales had not confined himself so strictly to Butte. Comparisons in various respects with other mining districts might serve as tying-in points to those not fortunate enough to see this camp for themselves; and it would seem that the statement regarding genesis, particularly the nature of the depositing solutions, might have been strengthened if citations had been made to other mining regions for which similar ideas have been held. It is, however, a sufficient task to record the geology of a single district so complex as Butte, and those who would combat Mr. Sales's hypotheses should remember that these have been devised to accord with an enormous store of hard facts gathered through 13 years of close personal observation. I feel greatly indebted to Mr. Sales for his contribution.

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<sup>1</sup> *Bulletin No. 77, May, 1913, p. 782.*

W. C. RALSTON, San Francisco, Cal.:—When you speak of the acidity of the inclosing granite; that is, the primary granite, what is meant? Do you refer to the per cent. of acid present, and also how does the acidity of the altered granite adjoining the veins compare with the normal unaltered granite? To me the line of demarcation would be rather indefinite, and this dividing line does not appear to be clearly defined.

MR. SALES:—"Acidity" when applied to rocks is a comparative term only and it refers to the relative amounts of silica present. The quartz-porphyry of Butte is more "acid" than the granite because it contains 4 or 5 per cent. more silica. The silica content of the altered granite associated with the vein is a widely variable constituent. Sometimes it is more siliceous and often less siliceous than the unaltered granite, depending upon the degree of alteration and many other factors. In general terms, the line of demarcation between altered and unaltered granite is well defined, though there may be a slow gradation between slightly altered and highly altered material.

MR. RALSTON:—Is it a highly acid rock?

MR. SALES:—The Butte granite runs about 64 per cent. silica.

MR. RALSTON:—Now, as to the altered granite, what percentage has it?

MR. SALES:—It is variable, sometimes higher, but often lower in silica than the normal rock.

J. W. RICHARDS, South Bethlehem, Pa.:—May I call attention to the fact that where chemistry touches the field of geology a knowledge of physical chemistry will greatly aid the geologist in solving his questions. It is a great thing to have a thousand million dollars' worth of copper, but to the real geologist there is more satisfaction in knowing how the copper got there. We are now possibly groping in the dark because of a lack of knowledge of the reactions of copper-bearing solutions under high pressures. I think that is one of the weak points of the paper, especially where it enters upon theory and speculation as to how the primary chalcocite was produced. I think we should go to the laboratory and get more experimental information as a preliminary and guide to our theory and speculation.

## Some Recent American Progress in the Assay of Copper-Bullion.

Discussion of the paper of Edward Keller, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 2093 to 2115.

GEORGE L. HEATH, Hubbell, Mich. :—In the admirable paper quoted, is mentioned the date when the 5-g. assay was first proposed as a standard for refined metal.

The author omitted, however, to mention a later paper,<sup>1</sup> which contains a proposal for the use of a single "stock solution" of mixed acids, which has been adopted by the American Brass Co. and others.

The suggestion is made that such a scheme would save time and manipulation with converter metal. Unless the low current of 0.5 ampere and the large excess of nitric acid, recommended by Mr. Keller, have been proved necessary to hold up antimony and selenium, the use of the mixed solution which we have adopted will permit the use of 1 ampere of current per square decimeter of cathode surface, until the solutions have become colorless. At this point, we wash the covers and reduce to 0.5 ampere to prevent oxidation or contamination. The ordinary split electrodes have been used. With strong current, at least, the use of an excess of nitric acid tends to the neutralization of the solution before the end of the period, from the formation of too much ammonia, and this is detrimental. Antimony deposits more easily than arsenic, and tends to drag the latter down with it. There must be some such explanation for the fact that we have made hundreds of deposits of pure cathodes from Lake material containing no antimony, but as high as 0.5 per cent. of arsenic. By placing an assay beaker in the Frary solenoid, or rotary device, a cathode deposit with less than 0.01 per cent. of impurity is easily obtained in one operation from 3 g. of whitneyite, carrying from 7 to 10 per cent. of arsenic. In such a case, it is necessary to test several times for end point and remove the plate as soon as no brown tint appears (at once) when hydrogen sulphide water is added to the test portion on the spot plate.

Edward Keller's proportions of solvent figure out as 14 cc. of strong nitric to 11.4 cc. of sulphuric acid (1.84).

Our stock solution is made up in the following proportions by volume: 7 cc. of nitric acid (1.42), 10 cc. of sulphuric acid (1.84), and 25 cc. of water. Ordinarily, 40 cc. is taken for a 5-g. sample,

<sup>1</sup> *Journal of Industrial and Engineering Chemistry*, vol. iii, No. 2, p. 74 (Feb., 1911).



unless the arsenic is over 0.5 per cent., in which case the amount of solvent is increased.

It may not be generally known that one chemist, Ferdinand Andrews, of the Raritan Works, is depositing regularly 10 g. of copper from refined metal in 16 hr. with the perforated cathode, described by Mr. Keller, and a double anode, consisting of an inner spiral and outer frame in one piece, similar to the Hollard type advertised by Eimer & Amend, New York. The current strength is 1 ampere, and the first solvent is pure nitric acid, to which is added 6 cc. of sulphuric acid and 10 cc. of ammonia, after the nitrate has been evaporated to the crystallizing point. Here, as in the single-mixture method, ammonium salts are depended upon to assist in holding back the impurities.

If the same quantity of sample can be plated out with half the current required by the solid cathode, or if 10 g. can be taken, the perforated cathode certainly offers advantages in the assay of refined metal as well as crude bullion.

*Removal of Selenium and Tellurium.*—When these elements are the principal impurity, they have for years been successfully removed by a very simple scheme which takes care of Mr. Keller's objection that the metals, under certain conditions, form compounds with silver, or copper, when reduced with sulphur dioxide.

The nitrate solution is evaporated with excess of sulphuric acid until the dry residue is white. Dissolve in 60 cc. of water and wash into a lipped beaker, placing the tall beaker under a funnel fitted with a 3-cm. filter. Heat the solution to boiling, remove from plate, and charge with SO gas for 10 min. Gas, free from chlorine, is generated by slowly dropping a saturated solution of C. P. sodium sulphite from a separatory funnel into a large round-bottom flask half filled with concentrated C.P. sulphuric acid. After settling a few hours, at least, filter into the original electrolytic beaker, and wash free from acid with hot water. Boil gently to remove most of the sulphur dioxide gas. Ignite the filter in a porcelain crucible at a red heat until the residue is oxidized, to volatilize the harmful elements.

Re-dissolve the residue in 1.5 cc. of nitric acid and add to the main solution, and electrolyze in the usual manner. A little more nitric acid and 10 cc. of ammonia may be added, if necessary, to hold back antimony and bismuth.

## Concentration of Slimes at Anaconda, Mont.

Discussion of the paper of Ralph Hayden, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 1443 to 1467.

JOHN V. N. DORR, Denver, Colo.:—Mr. Hayden has placed the metallurgical profession greatly in his debt for this valuable paper. The importance of such a complete description of the research work on which is based the building of a plant to add at least 10,000,000 lb. of copper per year to the production of the Anaconda Copper Mining Co., at small expense, will be appreciated by all our members, and especially those who are facing similar problems.

The information given in regard to the treatment methods discarded will be a great help to many workers, as it is often of as much importance to know what "not to do" as what method to adopt.

Some further comment on the tests of the Dorr thickener may be of interest, as they have led to developments which I believe will prove of great importance.

Before the Dorr thickener was installed, I had shown Mr. Laist reports from the Steptoe Valley concentrator, in which it was stated that one thickener 17 ft. in diameter was the equivalent in settling capacity of twelve 8-ft. cones, although the latter contained double the surface area. Mr. Laist had made careful tests on the settling capacity of an 8-ft. cone on Anaconda slime, and we naturally expected the thickener would show a much higher capacity for equivalent area.

When, as Mr. Hayden stated, the tests showed no increase, I realized that we were comparing it with a cone under test conditions, while the Steptoe results were based on operative conditions, and the explanation given by Mr. Waddell for the great difference had been, that "there is only one unit to watch instead of twelve, without the constant result of feed to twelve cones becoming unbalanced. Also the one  $1\frac{1}{2}$ -in. spigot used on the Dorr requires no attention compared with the dozen  $\frac{3}{4}$ -in. spigots of the cones."

I realized also as a result of the tests that the total settling area required to handle the immense tonnage of the Anaconda company would be enormous, and very expensive in view of the housing required by Montana climatic conditions. After studying the matter over, I told Mr. Laist that I believed a thickener operating in a much shallower tank would have nearly the same capacity. I asked him to test it out in the same tank filled 3 ft. deep, and stated that if my idea

proved correct, we could manufacture thickeners to operate with one mechanism in a number of superimposed shallow tanks. As a result of the tests we are now manufacturing for the Anaconda company 40 of what we call four-deck thickeners, each to operate in four tanks 28 ft. in diameter by 3 ft. 3 in. deep. This will reduce to nearly one-fourth the size of the building required for housing the settlers, and save in operating costs as well. Based on power measurements at other plants, and assuming one man giving constant attention to the operation of the plant, the cost of clarification, omitting interest, should not exceed 0.1 c. per 1,000 gal. clarified.

Carrying the idea still further at that time, I devised a system of trays to be installed in deep thickeners, for the purpose of making in effect a plurality of shallow tanks, each with its own feed and with a common overflow of clear liquid, and common or separate discharge of thick product.

A practical test along these lines at its mill has satisfied a large gold mining company, now cyaniding 1,800 tons of slime daily, that they can double their settling capacity with no additional expense for buildings, foundations, or tanks, and a very moderate cost for equipment. Both modifications of the thickener are now being patented, and I hope shortly to publish in the *Transactions* a full description of these recent developments.

The reduced cost of settling area thus obtained makes it probable that the machines can be used profitably in clarifying the water supply of cities depending on turbid river water, although I have no data as yet regarding the relative settling rates of a difficult metallurgical slime and river silt.

The installation at Anaconda should clarify enough water to supply a city of from 200,000 to 300,000 people, at the usual per capita rate of consumption.

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### Ore-Dressing Improvements.

Discussion of the paper of Robert H. Richards, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 81, September, 1913, pp. 2299 to 2303.

C. D. DEMOND, Anaconda, Mont. (communication to the Secretary\*):—Any one who has observed the increased efficiency of the Wilfley tables in a mill when fed from a reasonably good hydraulic classifier, as compared with tables fed from a *spitzkasten*, which is a very poor classifier, will agree to the advantage of "better classification." It must be gratifying to Dr. Richards to know that, directly or in-

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\* Received Oct. 17, 1913.

directly, many mill men are responding to his persistent advocacy of correct principles of ore dressing and are accepting the results of his investigations. As he says, these principles mean much for both the conservation of resources and the profit of operators.

When Dr. Richards gives us accurate figures as to the maximum size of free mineral grains in the tailings of the Wilfley table and of the vanner, they will be of a good deal of practical value in delimiting the proper fields for the Wilfley, the vanner, and the round table. He has coined the terms "free settling" and "hindered settling."<sup>1</sup> The series may be completed by adding "crowded settling," the main principle of action on both the vanner and the Wilfley table, which is the principle of separation in a mass of grains crowded as closely together as they can be and yet continue free to move between one another; and the occurrence of larger mineral particles in the Wilfley tailing than in that from the vanner is apparently caused by the more violent agitation, due chiefly to the purposely sudden reversal of the stroke. It seems likely that the agitation caused by the wash water dropping directly upon the concentrate on the vanner is more harmful than that due to the shake. For the very finest material that can be concentrated by usual methods, the round table is superior to the vanner because it does not have even the gentle agitation of the latter. The action on round tables is, not "crowded settling," but "film sizing,"<sup>2</sup> but agitation is harmful in the latter action. George Gates proved this harm 20 years ago: in making the first successful large-scale application of canvas tables in California gold mills he abandoned all shaking motion, although he had patented canvas tables to which such motion was applied.

I hope that Dr. Richards's results as to free mineral in tailings will cover different conditions as to violence of agitation, amount of wash water, and height from which both the feed and the wash water drop to the vanner, density of the pulp, and load per square foot. It will also be important to determine whether the efficiency of the Wilfley table can be increased by adopting a plain eccentric motion in place of the "quick return," which will lessen the violence of the agitation; and produce the travel toward the concentrate discharge end by means of a suitably steep, and adjustable, slope in that direction.

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<sup>1</sup> *Trans.*, xxvi, 7 (1896.)

<sup>2</sup> Richards: *Ore Dressing*, vol. ii., p. 644 (1903).

## **The Use of the Microscope in Mining Engineering.**

Discussion of the paper of Frederick W. Apgar, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 78, June, 1913, pp. 1011 to 1022.

L. C. GRATON, Cambridge, Mass.:—I presume I am one of the few who are exceedingly interested in microscopic work, and I am sure we have all enjoyed this paper very much. I will not attempt to express my own feelings in regard to it beyond saying that it seems to me that this sort of investigation and study has been overlooked and slighted, and its possibilities are very great. There are one or two details which impressed me, because they were novel to me, and one was the development of secondary galena with dull luster. I have never seen any galena which seemed to be secondary, and have never seen any that was secondary or primary that did not have a bright luster.

KIRBY THOMAS, New York, N. Y. (communication to the Secretary \*):—The present-day mining engineer is expected to "see into the ground farther than the point of the pick" and he is justified in making free claim to his ability to do so. Mr. Apgar has recorded the development of the application to the work of the engineer of a very useful but tardily recognized instrument—the petrographic microscope, an instrument which is helping to shatter the proverbial "point of the pick" limitation—and he has shown its use and its possibilities very clearly. Some further field examples of the use of the microscope in engineering problems may add to the appreciation of Mr. Apgar's scholarly paper. In exploration by diamond drills in the Sudbury, Ontario, nickel district it is often of great importance to determine when the drill has passed out of the norite and into the foot-wall formation. Structural calculations may give a clue to the expected point of contact, but the variations are considerable, and since to stop the drill before reaching the contact is futile, and to continue beyond it is needless, it becomes of theoretic and economic importance to determine positively the lithological nature of the core at critical stages in the work. In some places the foot-wall is an earlier norite, only distinguishable from the nickel norite (Sudburyite) by means of an examination of the rock slides with a petrographic microscope. Again, certain diabase dikes which cut the norite and the foot-wall formations cannot be easily or with certainty distin-

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\* Received Sept. 22, 1913.

guished megascopically from the norite. The determination, only possible with the high-power microscope, that the often highly altered rock gangue associated with outlying pyrrhotite masses in the Sudbury district is a phase of the nickel norite, is of evident importance in view of the fact of the invariable association of the norite and the nickeliferous pyrrhotite. From these random examples from actual working notes, it is evident that the microscopic laboratory is often quite as essential to the engineer in charge of explorations as is the assay laboratory to the metallurgist or to the miner.

Another point of application of the microscope should be considered. Often it is of no great importance, from a commercial point of view, that the exact species of the associated rocks of a mineral deposit should be determined, but the engineer owes a recognition to the science on which his profession is founded which should restrain him from incorrect, careless, or indefinite rock nomenclature in his reports and records. A few "standby" rock names, frequently wrongly used in mining literature, often cover obvious ignorance or indicate culpable carelessness. It is not to be expected that the busy field engineer can offhand "read" all the multitudinous rock species, but he can obtain a slide of the important rock formations he describes at a very insignificant cost, and likewise can have a lithological determination made by a specialist for a nominal charge, if desired.

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### Notes on the Metallography of Refined Copper.

Discussion of the paper of Earl S. Bardwell, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 79, July, 1913, pp. 1429 to 1441.

H. O. HOFMAN, Boston, Mass. (communication to the Secretary\*):—It is pleasing to the originators of the planimetric determination of oxygen in refined copper to see that the method has been taken up by a large smelting plant to be used in every-day work after it has been simplified to suit the new conditions. Several years ago Huntington and Desch<sup>1</sup> had improved our mode of working. They projected the developed negative on to a screen, traced the outlines of the picture with a pencil, drew a border, and measured one constituent with the planimeter. In order to give the work greater precision, they divided the area into squares of 1 cm. side, shaded the

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\* Received Aug. 26, 1913.

<sup>1</sup> *Transactions of the Faraday Society*, vol. iv., p. 51 (1908).

areas of one constituent, and estimated the proportions of shaded and unshaded areas. Mr. Bardwell's plan is simplicity itself, and the data given show that the results are all that can be expected.

The diagram, Fig. 6, showing the electric conductivity curve of refined copper as influenced by the combined presence of oxygen and arsenic plus antimony, shows how important it is to know something about the amount of oxygen present if we are to understand the effects other constituents may have which are present with the oxygen. The requirement for electrolytic copper advocated by Addicks,<sup>2</sup> that the electrolytic conductivity be satisfactory and the metal form a mechanically perfect casting, serves some purposes, but not all. The influence of oxygen upon the mechanical properties of copper which has not passed through an electrolytic plant is marked. It was studied by Hampe<sup>3</sup> in his classical researches, and was emphasized from the point of view of the copper smelter by Lewis,<sup>4</sup> who recently<sup>5</sup> reaffirmed his views in his protest against the specifications of the American Society for Testing Materials<sup>6</sup> of making electric conductivity the basis of a specification for copper which is not to be used for electrical purposes. Extended studies upon the influence of oxygen upon the limits of the harmful effects of impurities, such as arsenic, antimony, tin, and bismuth, upon the mechanical properties have been made by Johnson,<sup>7</sup> Greaves,<sup>8</sup> Archbutt,<sup>9</sup> Baucke,<sup>10</sup> and others.

The study of the influence of the combined presence of oxygen and impurities upon the electric conductivity of copper has been begun by Bardwell, who unfortunately has had to drop his investigation. A great deal of very accurate physical and chemical laboratory work will have to be done before a satisfactory answer can be given to this important question.

<sup>2</sup> *Trans.*, xxxiv., 985 (1903).

<sup>3</sup> *Zeitschrift für das Berg- Hütten- und Salinenwesen im preussischen Staate*, vol. xxi., p. 218 (1873); vol. xxii., p. 93 (1874); vol. xxiv., p. 6 (1876).

<sup>4</sup> *Engineering*, vol. lxxvi., p. 753 (Dec. 4, 1903); *Engineering and Mining Journal*, vol. lxxvii., No. 7, p. 284 (Feb. 18, 1904).

<sup>5</sup> *Metallurgical and Chemical Engineering*, vol. x., No. 9, p. 540 (Sept., 1912).

<sup>6</sup> *Year Book*, 1911, p. 127.

<sup>7</sup> *Journal of the Institute of Metals*, vol. iv., p. 163 (1910); vol. viii., p. 192 (1912).

<sup>8</sup> *Idem*, vol. vii., p. 218 (1912).

<sup>9</sup> *Idem*, vol. vii., p. 262 (1912).

<sup>10</sup> *Internationale Zeitschrift für Metallographie*, vol. iii., No. 3, p. 195 (Dec., 1912).

## The Great Falls Flue System and Chimney.

Discussion of the paper of C. W. Goodale and J. H. Klepinger, presented at the Batte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 1935 to 2010.

PROF. JOSEPH W. RICHARDS, South Bethlehem, Pa.:—Mr. Chairman, I would like to call attention to one valuable feature of the paper which may interest some: I have worked a good deal with the Pitot tube, and have always had difficulty with what is called the static end of that apparatus, so much so that I became almost hopeless of securing good results with it. I find here, however, what is stated to be a perfectly satisfactory static end for the Pitot tube, satisfactory under probably all conditions. I congratulate Mr. Klepinger on the design of that tube and the consequent improvement he has made in the technical measurement of the volumes of gases. I would also like to ask if the total volume coming out of the chimney per day could not be computed by chemical analyses of the SO and SO<sub>2</sub> in the gases, and calculation on the basis of the known weight of sulphur going out in a day; so that the Pitot tube measurements could be checked by a method independent of measurements in the flues.

J. H. KLEPINGER:—I think the volume of gases could be determined in that way. Those of a chemical turn of mind would go about it so, but I am not enough of a chemist to follow that method, and consequently I always look at the mechanical way to obtain the results.

HOWARD N. EAVENSON, Gary, W. Va. (communication to the Secretary\*):—The writer has been much interested in this very able paper presented by Messrs. Goodale and Klepinger, and particularly so in those portions of it relating to the measurement of the velocity through the flue and the settling of the dust in the flue chamber. The form of static pressure end developed for the Pitot tube will undoubtedly give very good results with the velocities measured, but with very high velocities—say above 10,000 ft. per minute—it is questionable whether the instrument will be substantial enough to resist the pressure unless it be made so heavy as to materially obstruct the flow of gases. The averaging manometer is an excellent device and the results obtained by it will probably be within the limits of

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\* Received Sept. 24, 1913.



accuracy of measurements up to velocities of about 6,000 ft. per minute.

In order to complete the data in the paper, the writer would suggest that if any traverses of the experimental flue were made, showing the different velocities in various parts of its area, that these be included in the final publication of the paper.

The curves shown in Plate IX of the relative efficiency of the various schemes used for dust arresting are evidently based on the average velocity in the experimental flue of 440 ft. per minute given in Table IV. Were any tests made of any of these schemes, using higher or lower velocities than this? The wire baffles are evidently the most efficient and economical of all the methods tested, at this velocity, and probably so at any other velocity, but undoubtedly tests 32 and 34, with the open flue, would have been much more efficient at much lower velocities, as would probably test 37. The enormous volume of gases to be handled would of course have precluded the use of any scheme involving a very low velocity—say 100 to 200 ft. per minute; but probably the various tests made by the authors have enabled them to form an opinion as to the effect of lower velocities on the efficiency of the various methods tested.

From the data given on p. 1965, the average weight of dust in the gases, per cubic foot, is slightly over 48 lb. Would this be a fair average weight of dust in all experiments?

Great credit is due both of the authors for the interesting presentation of the data obtained in their various tests and in the successful working out of their design of flue system and chimney, both in its details and in its entirety.

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### Hydro-Electric Development in Montana.

Discussion of the paper of Max Hebgén, presented at the Butte meeting, August, 1913, and printed in *Bulletin* No. 80, August, 1913, pp. 1910 to 1933.

A MEMBER:—Have there been any definite studies made in the hydrology of this system? That is to say, what is the total extent and area of the drainage or catchment basin above these plants? What is the total annual precipitation, and what is the percentage of run off? That is a very interesting question to engineers and a question engaging a great many, because, unfortunately, there is not the amount of information on that subject which there ought to be.

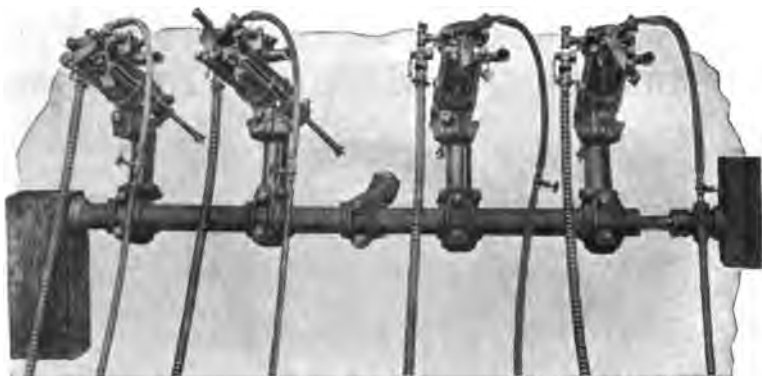
FRANK SCOTTEN, Great Falls, Mont.:—There are a great many figures on the subject, but I am not familiar enough with them to quote from memory. The entire drainage area has been figured in unit feet, and the precipitation is well known, but I am not familiar enough with it to quote.

PROF. JOSEPH W. RICHARDS, South Bethlehem, Pa.:—I think this paper is a very fundamental one, because it goes right to the root of the future development of Montana as a State, and of its industries. It is exactly in line with what is being done in other parts of the world where coal is scarce and where water powers are plentiful, and I see in it the promise and the prospect of great development which can put Montana ahead of perhaps many other States which have good supplies of coal. I would like to call further attention to one detail of the use of this power, which is, that when a large amount of it is in use for traction and lighting, there are necessarily peaks (speaking in the electrical sense) where the power is used heavily, and deep valleys where the power is used only lightly. You should therefore get from the electric power companies power at certain parts of the day and in certain parts of the year very much cheaper than if you use it continuously. In the East we are finding considerable uses for cheap power used in this way during limited periods.

I take it for granted that in these mining States you have a large use, for instance, for steel castings. I am told that you make very few in Montana. In the East we have electric furnace plants which are using power in the "valleys" of the power supply companies and are making steel castings at a considerable profit, although they are paying as much as \$60 a horse power-year for their power. This is just one example of how you can build up your own industries, help yourselves by having your own supply of necessary materials for the mining industry, and save money from going out of the State. This is only one of a dozen or more electro-metallurgical or electro-chemical industries which might be of direct use to your people and which certainly could be established here within a short time.

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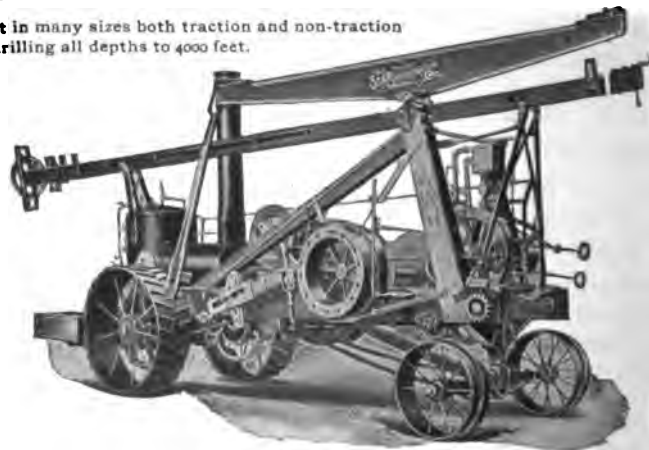
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The volume contains also a Biographical Notice of Dr. Emmons by his associate and friend, Dr. George F. Becker, and a comprehensive Biographical Index of the Science of Ore-Deposits, prepared by Prof. John D. Irving, of the Sheffield Scientific School of Yale University.

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*Signature.*

*Dated* \_\_\_\_\_ *191*

## ARTICLE II.—MEMBERS.

SEC. 2. The following classes of persons shall be eligible for membership in the Institute, namely: as Members, all professional mining engineers, geologists, metallurgists, or chemists, and all persons actively engaged in mining and metallurgical engineering, geology, or chemistry; as Associates, all persons desirous of being connected with the Institute who in the opinion of the Board of Directors are suitable.

Every candidate for election as a Member, Associate, or Junior Member must be proposed for election by at least three Members or Associates, must be approved by the Committee on Membership, as prescribed in the By-Laws, and must be elected by the Board of Directors.

# BULLETIN OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.

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1913

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Entered as second class matter, October 16, 1911, at the post office at Philadelphia, Pa., under the Act of March 3, 1879.

---

## AN UNUSUAL OPPORTUNITY FOR INSTITUTE MEMBERS

to increase or complete their sets of the *Transactions*.

In order to encourage the custom of members increasing each year the number of Volumes of the *Transactions* in their private libraries until the sets are complete, the Board of Directors has authorized the sale of *Transactions* previous to the year 1913 at the following greatly reduced rates. This offer is made effective for sales made only during the year 1914, and applies only to members in good standing, and to libraries. The reduced price automatically ceases to apply to any volume when the total number of such volume left in stock is reduced to fifty (50).

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### BOARD OF DIRECTORS.

*Meeting of Nov. 21, 1913.*—The President reported the appointment of the officers and members of the Committee on Non-Metallic Minerals, published elsewhere in this *Bulletin*.

The President appointed the Executive Committee of the New York Section as a local committee to have charge of the Annual Meeting of the Institute in February, 1914, with power to add to their numbers.

It was voted that the Chairman of each Technical Committee be made *ex officio* a member of the Committee on Papers and Publications.

At the request of the Secretary, Burr A. Robinson was appointed Assistant Secretary of the Institute.

E. Gybbon Spilsbury was nominated as representative of the Institute on the John Fritz Medal Board of Award.

It was voted that the next summer meeting of the Institute be held in Salt Lake City in August, 1914, with power to the Executive Committee to fix the exact date.

Substantial reduction was made in the price of the back *Transactions* of the Institute in accordance with the notice published on p. i of this *Bulletin*.

The By-Laws of the Montana Local Section were approved.

The printing contract for the year 1914 was made with the Maple Press.

Thirty-eight Members, one Associate and three Junior Members were elected.

---

### 1914 DUES.

All dues are payable in advance on the first day of each calendar year, in accordance with Article III, Section 1, of the Constitution. Many members have been in the habit of paying their dues at the end of the year, but the Constitution decrees that, if any Member, Junior Member or Associate is in arrears for four months, the *Bulletin* shall no longer be sent to him, and he shall be notified by the Secretary of the Institute that no publications will be sent him until his arrears are paid. The Constitution also provides that a notice to this effect shall be published in the last number of the *Bulletin* of each calendar year, and that any Member, Junior Member or Associate in arrears for one year shall be dropped from the rolls.

---

**Dressing Rooms at Headquarters.**—The Institute maintains at its headquarters in New York free dressing rooms, which are available to members between the hours of 7 a.m. and midnight. Any of the elevator-men will advise where the rooms are located, and members can obtain access to the building even after the front door is closed by ringing the bell provided for that purpose.

**EMMONS VOLUME ON ORE-DEPOSITS.***A continuation of the "Posepny" Volume.*

Comprising papers descriptive of ore-deposits and discussions of their origin, edited, with an introduction, by Dr. S. F. Emmons. The volume contains also a Biographical Notice of Dr. Emmons by his associate and friend, Dr. George F. Becker, and a comprehensive Bibliographical Index of the Science of Ore-Deposits, prepared by Prof. John D. Irving, of the Sheffield Scientific School of Yale University. Dr. Emmons had finished his editorial work and written his Introduction before his lamented death in 1910; and the Volume contains his last words upon the subject to which he had given the work of his life, and on which he was justly regarded as the foremost authority.

*Contents.*

- Genesis of Certain Ore-Deposits. By S. F. EMMONS.  
 Structural Relations of Ore-Deposits. By S. F. EMMONS.  
 Geological Distribution of the Useful Metals in the United States. By S. F. EMMONS. Discussion, by JOHN A. CHURCH, ARTHUR WINSLOW, S. F. EMMONS, and WILLIAM HAMILTON MERRITT.  
 Torsional Theory of Joints. By GEORGE F. BECKER. Discussion, by H. M. HOWE, R. W. RAYMOND, C. E. BOYD, and GEORGE F. BECKER.  
 Allotroplasm of Gold. By HENRY LOUIS.  
 Superficial Alteration of Ore-Deposits. By R. A. F. PENROSE, JR.  
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The volume contains 1002 pages. Price, bound in cloth, \$5; in half morocco, \$6. Both the Emmons and the Posepny Volumes on Ore-Deposits, bound in cloth, \$8; in half morocco, \$10.

**READY FOR DISTRIBUTION.**

## PERSONAL.

(Members are urged to send in for this column any notes of interest concerning themselves or their fellow-members.)

Members and visitors who registered at Institute headquarters during November:

George W. Otterson, Maunson, B. C.  
E. L. C. Ayres, Bound Brook, N. J.  
M. Russell, Bound Brook, N. J.  
Carlo Spruyt, Antwerp, Belgium.  
Charles A. Pringle, San Francisco, Cal.  
E. S. Bardwell, Great Falls, Mont.  
Sir Robert Hadfield, London, England.  
James A. Barr, San Francisco, Cal.

Roy H. Allen, Chihuahua, Mexico.  
George A. Packard, Boston, Mass.  
Richard C. Patterson, Jr., Kansas City, Mo.  
Francis C. Phillip, Pittsburg, Pa.  
M. H. Kuryla, Mexico City, Mexico.  
Arthur Chippendale, Mexico City, Mexico.  
F. Danvers Power, Sydney, Australia.

Alexander H. Smith has been placed in charge of the Teck-Hughes mines, Kirkland Lake, Ontario, Canada.

Stanley A. Easton and James F. McCarthy are members of a commission appointed by the Governor of Idaho to draft a workingmen's compensation act for that State.

J. Campbell Besley, Life Member, has resigned from the Institute.

J. V. N. Dorr, of the Dorr Cyanide Machinery Co., has opened an office at 50 Church Street, New York, N. Y.

J. O. W. Applegren has accepted a position as Metallurgist and Mill Superintendent with the Curtz Consolidated Mines Co., Mogul, Alpine county, Cal.

Edwin G. Banks has been made General Superintendent of the Waihi gold mine, Auckland, N. Z.

Henry Kehoe has been appointed engineer in charge of mining operations of the London-Arizona Consolidated Copper Co., Pinal county, Ariz.

Archie M. Hazard is installing a mill for Cristóbal Dilon at his copper properties in Chacarilla, Bolivia.

Willet G. Miller, LL. D., Provincial Geologist, was tendered a dinner by the foremost mining men of Canada at the Toronto Club. G. G. S. Lindsey, K. C., was Chairman, and those who spoke in enthusiastic appreciation of the services rendered by Dr. Miller to the science as well as the practice of mining included Hon. Frank Cochrane, Minister of Railways and Canals; Hon. W. H. Hearst, Minister of Lands, Forests and Mines; Dean Galbraith, Toronto University; Professor Goodwin, Queen's; Theodore Dennis, Superintendent of Mines, Quebec; F. H. Guigan; R. W. Brock; T. W. Gibson, Deputy Minister of Mines; Col. A. M. Hay; Clifford Smith; H. Mortimer-Lamb, Secretary Canadian Mining Institute, and J. A. McEvoy. A characteristic portrait painted by J. W. L. Foster was presented to Dr. Miller.

E. P. Ross has been appointed Superintendent of the new furnace of the Colonial Iron Co., at Riddlesburg.

---

**Mining Books Wanted.**—A Mining School in the United States desires to purchase books for a Mining Library. Those who have books which they would like to dispose of may communicate through the office of the Institute.



**ENGINEERS AVAILABLE.**

(Under this heading will be published notes sent to the Secretary of the Institute by members or other persons.)

Member, graduate of College of Mines of University of California, with 12 years' operating experience in mining and milling in California, Canada, and Mexico, is open for engagement. Speaks Spanish fluently. No. 17.

Mining engineer and metallurgist open for engagement Jan. 1 as superintendent of mines or constructing engineer. Technically educated, with 14 years' experience in United States and Latin America in concentration, amalgamation, cyaniding, constructing. At present building large modern all-sliming cyanide mill in Central America. No. 18.

Member, mining and metallurgical engineer, is open to engagement. Specialty, the treatment of copper ores. Nine years' experience in the operation and also in the design and erection of copper smelteries. Four years true pyrite smelting. Able to organize the administration, accounting, etc., of a large plant. Speaks a fair amount of Spanish, Russian, German, and French. Qualified to take charge of a large smeltery, or to act as assistant to manager of a combined mining and smelting concern. No. 19.

Member, technical graduate, 33 years old, 11 years' experience as chemist, metallurgist, and superintendent of lixiviation plant and in charge of construction of cyanide mill, is open for engagement. Speaks Spanish. No. 21.

Member, lately with the Bishop Creek Milling Co., California, is now open for engagement as mine superintendent or superintendent of construction of mine and mill structures. No. 25.

Member, graduate engineer, age 35, with 15 years' practical experience in mining and railroad work, at present assistant manager and chief engineer of a large mining company, is desirous of locating convenient to good schools for his children. No. 28.

Member, technical graduate, with 10 years' experience in metal mining in Mexico, two years in talc mining and one year in iron mining in the United States, is open for engagement. No. 29.

Member, graduate of McGill University in mechanical engineering, with 12 years' experience in mining mica, gold, silver, and copper in Ontario and the West, and in hydraulicking in Alaska, is open for engagement. Last four years as engineer for a steel construction company. No. 31.

Member, technical graduate, aged 30, with eight years' experience in copper smelting, is open for engagement. At present acting superintendent of a large copper smelter. No. 33.

Member, technical graduate, aged 35, with nine years' practical experience in smeltery, mill and mine design, construction and management, especially lead and zinc, and four years Associate Professor of Mining Engineering, is open for engagement. Specialty, mine equipment. No. 34.

Member, 34 years old, married, nine years responsible position in South America. Excellent knowledge of Spanish, Latin-American people and customs; with present employer seven years; six years as manager and legal representative of a mining company; desires to make a change April, 1914. Prefers position requiring energy, executive ability, business tact and practical knowledge dealing with political and legal authorities, rather than strictly technical position. No. 35.

Technical graduate, 34 years old, married, with 12 years' experience in ore testing, mill designing, construction and operation, principally in Mexico, open for engagement. No. 36.

Technical graduate, married, with four years' experience in assaying, surveying, sampling, and mine supervision in Utah and Mexico, open for engagement. No. 37.

Member, with 15 years' experience in exploration and development work for a large corporation, will shortly be available for a similar position, preferably to operate in the tropics. Speaks German, Spanish, and the Scandinavian languages. No. 38.

Young man, recent technical graduate, now employed at Eastern smelter, desires a position in iron and steel work, preferably with an automobile company. Good knowledge of metallography. No. 39.

## IRON AND STEEL COMMITTEE.

ALBERT SAUVEUR, *Chairman.*

A. A. STEVENSON, *Vice-Chairman.*

HERBERT M. BOYLSTON, *Secretary*, Abbot Bldg., Cambridge, Mass.

John Birkinbine,  
William H. Blauvelt,  
James Gayley,  
Henry D. Hibbard,  
Henry M. Howe,  
Robert W. Hunt,  
J. E. Johnson, Jr.,

William Kelly,  
Charles Kirchhoff,  
Richard Moldenke,  
Joseph W. Richards,  
C. F. W. Rys,  
E. Gybbon Spilsbury,

J. S. Unger,  
Felix A. Vogel,  
Leonard Waldo,  
William R. Walker,  
William R. Webster,  
Frederick W. Wood.

The following papers have been promised for the February meeting of the Institute and, although the manuscripts have not all been received at the time of this writing, we have good reason to expect them in time to be printed.

ALBERT SAUVEUR, *Mayari Steel.*

J. E. JOHNSON, JR., *The Quality of Cast Iron as Affected by Oxygen, Nitrogen, and Other Elements.*

J. V. EMMONS, *The Surface Decarbonization of Tool Steel.*

CAPT. R. W. HUNT (title not yet received).

W. S. POTTER, *Manganese Steel* (title not yet received).

A. N. DIEHL, *Blast-Furnace Gas Cleaning.*

ARTHUR WEST, *Large Gas Engines in the Iron Industry.*

——— *Large Steam Turbines in the Iron Industry.*

Invitations have been sent out to several of the large steel manufacturers to contribute papers on the Duplex process, and we are also hoping for a paper on Oxygen and Steel.

It is urged that those who wish to contribute papers for the February meeting, who have not signified their intention of doing so, will write to the Secretary at once, giving the titles of their papers. If they wish papers preprinted so that adequate discussion may be obtained, it will be necessary to have the manuscripts in the hands of the General Secretary by Dec. 30, at the very latest; and not more than one or two papers can be preprinted of those received as late as that date.

HERBERT M. BOYLSTON, *Secretary.*

## COMMITTEE ON MINING GEOLOGY.

JAMES F. KEMP, *Chairman.*JOHN W. FINCH, *Vice-Chairman.*R. A. F. PENROSE, JR., *Vice-Chairman.*L. C. GRATON, *Secretary, Harvard Geological Museum, Cambridge, Mass.*

Ralph Arnold,  
H. Foster Bain,  
John M. Boutwell,  
H. A. Buehler,  
William H. Emmons,  
Henry Landes,

Alfred C. Lane,  
Charles K. Leith,  
R. V. Norris,  
Ezequiel Ordoñez,  
William B. Phillips,  
Joseph H. Pratt,

Heinrich Ries,  
Reno H. Sales,  
William G. Sharp,  
Charles H. Smyth, Jr.,  
Henry L. Smyth,  
Josiah E. Spurr.

The Committee on Mining Geology has requested the authorities of the Institute to assign one afternoon of the Annual Meeting in February to it for the discussion of the following questions, all of which are of live interest to-day. It is planned to take them up in order; to have speakers or contributors ready upon each topic; and to draw upon the great and widely scattered membership of the Institute for such new data and new light as may be available. An invitation is therefore hereby extended to all members who may be interested to send contributions, even if brief, to the discussions:

1. To what depth below the surface do the standing ground-waters extend?

2. To what extent is chalcocite a primary, and to what extent a secondary, mineral in ore deposits?

3. To what extent are the contact zones, often called garnet zones, produced by intrusive rocks from limestone walls, due to recrystallization of matter original with the limestones; and to what extent are they and their associated ores due to contributions from intrusive rocks

1. According to earlier views, the ground-water was supposed to extend deep within the earth and to constitute a more or less actively circulating medium, which leached the rocks of the ores and gangue and brought the dissolved substances to be precipitated in the trunk channels. Much experience with bore-holes and with deep mines, however, has tended to show that the water, except perhaps in the form of mere dampness in the rocks, or as isolated pockets of peculiar composition, only extends to comparatively shallow depths, such as a thousand feet or less. Below this level the rocks are practically free from water, unless the workings are in a locality of recently extinct igneous action, such as the Comstock lode. Therefore, if in deep mines the water is impounded in the upper levels there is little or no need of pumping from lower levels; or if the water is not impounded, but follows the workings downward, the amount does not increase because of added depth. Experience in as many deep or moderately deep mines as can be placed on record will be of interest and value. The matter is of great importance in its bearing on long-trusted theories for the formation of veins.

Papers bearing immediately upon the question will be found in the publications of the Institute as follows:

Posepny, F., *Trans.* 23: 197-369, 1894; Rickard, T. A., *Trans.* 23: 589-591; 30: 367-403, 1900; Van Hise, C. R., *Trans.* 30: 27-177, 1900; 31: 292-302, 1901; Kemp, J. F., *Trans.* 31: 169-198, 1901; 33: 699-714, 1902; *Bull. A. I. M. E.*, April, 1913.

2. Some of the points to which discussion might well be directed are noted below. All other matters relating to this mineral will of course be welcomed. Any contribution regarding the conditions of formation and occurrence of related or associated minerals, particularly bornite, chalcocopyrite, covellite, native copper, cuprite, and the carbonates, will undoubtedly aid in elucidating the difficult and important question of chalcocite occurrence.

- A. If primary chalcocite exists, in what way may it be distinguished from secondary chalcocite—any differences in color, luster, hardness, crystalline structure, composition, stability?
- B. What are the positive evidences of secondary origin of some chalcocite?
- C. Is "sooty" chalcocite invariably secondary?
- D. Is massive (*i. e.*, not "sooty") chalcocite invariably primary?
- E. In what places and under what conditions is chalcocite found below the water level?
- F. Does secondary chalcocite form below the water level?
- G. How deep has chalcocite that is positively secondary been found? Does chalcocite from deep levels show different associations and structural features from that known to be secondary?
- H. What data can be gathered regarding the chemical character of mine water or ground-water at and near places of secondary chalcocite deposition?
- I. What other minerals are deposited with chalcocite in the zone of enrichment or sulphide regeneration?
- J. What kind of structural relationship do they show toward the chalcocite?
- K. Can the "eutectic" or "micrographic" texture be produced by replacement processes?
- L. Is secondary chalcocite ever formed by simple deposition, without replacement of some other substance?
- M. Is secondary chalcocite ever formed by replacement of non-metallic or gangue minerals?
- N. Of what nature—primary or secondary—is the chalcocite of the disseminated deposits in sediments, particularly in or near "red beds" in Colorado, Arizona, New Mexico, Texas, etc.; in the Triassic traps of New Jersey; in the basic lavas of Alaskan and northern Canadian regions; in the veins occasionally found associated with the native copper of the Lake Superior district; in the great deposit of the Bonanza mine, Alaska?

A list of papers bearing upon this topic follows:

Emmons, S. F., *Trans.* 30: 177-217, 1900; Van Hise, C. R., *Trans.* 30: 109-113, 1900; Sales, R. H., *Bull. A. I. M. E.* 80: 1523-1621, 1913; also important papers not in the institute publications, as follows: Kemp, J. F., *Economic Geology*, Vol. 1, 11-24, "Secondary Enrichment in Ore Deposits of Copper," 1905; Emmons, W. H., *Bull. U. S. G. S.* 529, "The Enrichment of Sulphide Ores," 1913; Ransome, F. L., *Economic Geology*, Vol. 5, 205-220, "Criteria of Downward Sulphide Enrichment," 1910; Tolman, C. F., Jr., *Mining and Scientific Press*, Vol. 106, 38-43, and 141-145, and 178-182, "Secondary Sulphide Enrichment of Ores," 1913; Weed, W. H., *Bull. Geol. Soc. of America*, Vol. 11, 179-206, "Enrichment of Mineral Veins by Later Metallic Sulphides," 1900.

3. In earlier years, the zones of lime-silicates, of which garnet is the commonest mineral, but among which are also to be numbered wollastonite, diopside, epidote, vesuvianite, scapolite, and several rarer species, were believed to be due to the recrystallization of the substance of the limestone, under the influence of the hot intrusive rock, aided perhaps by

emitted vapors. Only those limestones in which silica and alumina were rather richly present would thus yield the zones; otherwise crystalline limestone would alone result. In extended sections of limestones some beds or groups of beds which contain these earthy ingredients are almost always found. The argillaceous beds were believed to have furnished the zones, while the relatively pure limestones furnished the marbles.

Analyses have shown, however, that the garnet is very largely a lime-iron variety instead of one containing only lime and alumina in composition with silica. Since limestones are habitually low or lacking in iron it became necessary to draw upon some other source than the limestones for the supply of iron, and naturally the intrusive rock was the alternative. The large bodies of magnetite or specular hematite which often appear in the zones strengthened the belief. Analyses of the limestones outside the zones, and apparently representing the original rock from which the zones were produced, proved in a number of cases to contain very small percentages of alumina and silica and still less iron. Without contributions from the intrusive rock, it seemed difficult to account for even the lime-alumina garnet.

On the other hand, some have inferred that the magmatic waters from the igneous mass have dissolved and removed large amounts of the carbonate of lime, but have left behind increased proportions of the ordinary insolubles, silica and alumina. In the end the recrystallization of these residues yielded the zones. Contraction of the limestone bordering on the intrusive and affected by the zones to one-third or less of its original mass might be involved, but was still believed possible.

In taking part in this discussion members of the Institute would greatly aid if they would interpret new cases in the light of these views; would test limestones and garnets by analysis; and would record the order of formation of the minerals and ores of the zones. Usually the lime-silicates first form and are followed by the magnetite and this by the sulphides of iron and copper. This order, while usual, is not invariable.

The following papers are of interest:

Lindgren, W., *Trans.* 31: 226-244, 1901; Weed, W. H., *Trans.* 33: 715-746, 1902; Kemp, J. F., *Trans.* 36: 178-203, 1905; Stewart, C. A., *Bull. A. I. M. E.*, May, 1912, 455-505.

*Bulletin* 338 of the U. S. Geol. Survey, by C. K. Leith and E. C. Harder, on The Iron Ores of the Iron Springs District, Utah, should also be read. Although not in the publications of the Institute, it is readily accessible. In recent numbers of the magazine *Economic Geology* are suggestive papers and discussions.

J. F. KEMP, *Chairman*,  
L. C. GRATON, *Secretary*.

**COMMITTEE ON PRECIOUS AND BASE METALS.**CHARLES W. GOODALE, *Chairman.*L. D. RICKETTS, *Vice-Chairman.*DARSIE C. BARD, *Secretary*, Montana State School of Mines, Butte, Mont.

Leonard S. Austin,

David W. Brunton,

Theodore B. Comstock,

Stanley A. Easton,

Samuel S. Fowler,

Thomas J. Grier,

Hennen Jennings,

Edmund B. Kirby,

Charles W. Merrill,

Willet G. Miller,

Albert F. Schneider,

George C. Stone,

Benjamin B. Thayer.

The Committee aspires to make the *Transactions* of the Institute a representative record of current metallurgical practice. To this end we ask the co-operation of metallurgists and mill men in preparing papers on present methods at the plants with which they are associated. Also if there are any papers now being prepared on these subjects for the *Transactions* the Committee is desirous of being informed of the title and author's name.

C. W. GOODALE, *Chairman.*D. C. BARD, *Secretary.***COLUMBIA LOCAL SECTION.***Executive Committee.*F. A. THOMSON, *Chairman.*GEORGE W. RODDEWIG, *Vice-Chairman.*L. K. ARMSTRONG, *Secretary-Treasurer,*

P. O. Drawer 2154, Spokane, Wash.

R. S. McCAFFERY.

*Annual Meeting, Wallace, Idaho, Nov. 15-16, 1913.*

The third annual meeting, which was also the eighth consecutive meeting and the second to be held in the Cœur d'Alène district, was held in Wallace, Idaho, Nov. 15-16, 1913, with side trips to Kellogg-Wardner, Larson, and Mullan, where several mills were visited. The meeting was held jointly with the Montana Section, about 50 members and guests being present. Headquarters were in the Samuels Hotel, sessions being held in the public library. The arrangements and program were in the hands of the following local committee: George W. Roddewig, W. Earl Greenough, H. M. Childs.

At 2.30 p.m., Nov. 15, the first session was called to order by Prof. F. A. Thomson, member of the Executive Committee, adjournment being taken to the Mine Rescue car, where Mr. Anderson and his assistant entertained the visitors for nearly two hours by demonstrations of mine-rescue and first-aid practice, after which the party visited the Hercules mill, mention of which was made in the report of last year when the Section visited the plant. There are, however, several important alterations and additions to the flow-sheet to be noted, such as substitution of Chilean and Hardinge mills for the Huntington mills in the regrinding department; rearrangement of the tables and slimers, with a noticeable addition of the later models of the Franz machines, and the installation of the Wyman flotation process, which has been tried out, or is being tested, with more than ordinary success, on the middlings in several of the mills of the district, the Green Hill Cleveland mill being provided with a 100-ton unit, partly described below:

The feed consists of middlings, 7 parts water to 1 of solids, pumped to a settling tank, from which the pulp, thickened to a consistency of 4 to 1, is drawn off by spigots to a Wyman dewaterer, from which it is passed to the mixing box with moisture reduced to about 20 per cent. Here a weak acid solution is added and the mixture goes to the separation tank, where the sulphides are floated off to a tank where they settle; part of the acid solution is caught in a sump to be returned to the solution tank. The settled concentrates are drawn into a second dewaterer, where the acid solution is recovered, the concentrates going to Franz tables, where the lead and zinc are separated. Extraction varies between 60 and 85 per cent. of the zinc and from 60 to 75 per cent. of the lead, the wide variation being no doubt due to the experimental stage which the process is still in. The following items of cost, submitted as approximate only, are based upon operation of a 30-ton plant, whereas labor, which is the most expensive item, would be no greater for a plant of 150 tons per day:

|            | Per Ton.     |
|------------|--------------|
| Acid ..... | 20 to 30 lb. |
| Coal.....  | \$0.10       |
| Power..... | 0.03         |
| Labor..... | 0.30         |

The process was developed and is being operated by George H. Wyman, Jr.

Promptly at 7.30 p. m. the second session was called to order by James F. McCarthy, local member of the Executive Committee, who, after welcoming the visitors, called Prof. F. A. Thomson to the chair.

Upon taking the chair, Professor Thomson asked D. C. Bard, Secretary of the Montana Local Section, and E. Jacobs, Secretary of the Western Branch of the Canadian Mining Institute, to take chairs at the speakers' table. He congratulated the local committee and other members and citizens on their well-arranged program, thanking them on behalf of the visiting members and guests.

The following papers were then presented:

Electric Smelting of Lead and Zinc Ores, by Prof. R. S. McCaffery. Discussed by the Chairman, F. G. Cottrell, F. M. Smith, Rush J. White, E. Jacobs, and others.

Ore Dressing at the Federal Mining & Smelting Co.'s Morning Mill, by Rush J. White. Discussed by the Chairman, F. S. Rowe, George H. Wyman, Jr., William J. Hall, D. C. Bard, S. R. Moore, E. Jacobs, W. E. Greenough, and others,

Immediately following the adjournment of the joint session, the members of the Spokane Local Section met and transacted the following business:

Adoption of the report of the Secretary-Treasurer.

By a vote of 15 to 4 the name of the Spokane Local Section was changed to Columbia Local Section.

A vote of thanks was extended to the retiring Chairman.

By unanimous consent the Secretary was instructed to cast the ballot electing R. S. McCaffery, F. A. Thomson, G. W. Roddewig, and L. K. Armstrong to the Executive Committee, there being no other nominations.

There being no further business the meeting adjourned.

Later the following officers were elected:

Prof. F. A. THOMSON, *Chairman*.

GEORGE W. RODDEWIG, *Vice-Chairman*.

L. K. ARMSTRONG, *Secretary-Treasurer*.

At 7.30 a. m., Nov. 16, the party went by special train to Kellogg, where they visited the Bunker Hill & Sullivan concentrating mill, tailings plant and engineering department, and the Y. M. C. A.

The Bunker Hill & Sullivan is the only large mine in the district where no hand sorting of the high-grade ore is employed. In the mine a portion of the waste is removed and thrown into the stopes, the remainder is sent to the surface, crushed and concentrated, the tails being reground, passed through classifiers and over slime tables. There have been some changes during the past year; all the principal underground openings are being concreted, following a disastrous fire which was referred to by E. P. Dudley in his paper on The Use of Oxygen Helmets in Mine Fires, which was read at the Rossland meeting in May. It was determined by the management to prevent another such disaster. At the mill jigs are being installed to remove a portion of the lead in the middlings prior to regrinding, one of these already having been put into commission with satisfactory results. Some experimenting is being carried on with flotation, and a plant will doubtless be added to the flow sheet, probably of the Wyman type. The tailings plant has resumed operations, the feed, carrying about 2 per cent. of lead, being delivered to a belt conveyor by means of a bucket drag operated by a system of cables and donkey engine. Crushing, fine grinding, and sliming secures a small margin of profit. With about 600,000 tons to work over, the plant has a daily capacity of about 600 tons. In the engineering department there are several mine models representing every phase of the work, from flat plates to represent the different levels, properly colored and set vertically one above the other at proper distances to meet the horizontal scale, to the more complicated yet equally accurate model which includes levels and stopes done in color. The most improved type is that of the Caledonia, where celluloid has been employed, harmonizing the model to actual conditions and through which every detail of the work may be seen. In sections, it is possible to remove any portion of the model for closer inspection. A new concrete building houses the engineering and official staff. In connection with a safety station a "smoke house" has been erected where a rescue team is given a rigorous exercise once each week, under rather strenuous and realistic mine-rescue conditions. Some 50 men are prepared to take service whenever called upon. The B. H. & S. property was never in better physical condition nor producing more lead and silver. The No. 1 unit is being prepared to serve the Caledonia mine, which will soon be operating to capacity. Both Nos. 1 and 2 mills have been described; No. 1 by G. Caetani in *Mining Magazine*, vol. ii, No. 5, p. 361 *et seq.*, and No. 2, by R. S. Handy in *Trans.*, xliii, pp. 685-692.

Returning to Wallace at noon, where luncheon was served, a special train took the party to Larson and Mullan, where the mills of the Snowstorm, National, and Morning were inspected. The first named is the only mill in the district operating on copper ore, that of the National not yet being in commission.

The Snowstorm mill has been described in the technical press, the only alterations being the installation of Deister tables, which are giving excellent satisfaction.

When the National mill is completed it will be the last word on mill construction in the district. It was designed by John M. Callow, of Salt Lake City, who assembled standard types of machinery for every department of the plant; the only real novelty is a Symons disc crusher, man-



ufactured by Chalmers & Williams. The building is well along; concrete foundations, galvanized iron roof and siding are already in place, the machinery is being rapidly assembled and will soon be housed. It will be well into next year before the mill will be in commission.

In the finishing department of the Morning mill extensive alterations and additions have been made. Where one Hardinge mill was working alone last year there are now six of the 8-ft. size preparing feed for the Maquisten tube department, which has been much enlarged and now takes care of the entire tailing product of the plant. This department, however, is now dividing honors with the Wyman process, now being tried out in an adjacent room.

Returning to Wallace, a banquet, which began promptly at 7.30 p.m., was only brought to a close at midnight after a long list of toasts. William J. Hall, Assistant General Manager of the Federal Mining & Smelting Co., acted as toastmaster.

Upon motion by L. K. Armstrong, Secretary of the Columbia Local Section, seconded by D. C. Bard, Secretary of the Montana Local Section, J. N. Pott, of Puget Sound Local Section, and E. Jacobs, Secretary of the Western Branch of the Canadian Mining Institute, a vote of thanks was extended to the Hercules Mining Co., U. S. Mine Rescue Car, Bunker Hill & Sullivan Co., Snowstorm Mining Co., National Mining Co., Federal Mining & Smelting Co., newspapers of the district, local members of the Institute, and especially Messrs. W. Earl Greenough, George W. Roddewig, and H. M. Childs, members of the Program Committee, for facilities extended and courtesies received; after which the banquet passed into history.

L. K. ARMSTRONG, *Secretary*.

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## BOSTON LOCAL SECTION.

*Executive Committee.*

ROBERT H. RICHARDS, *Chairman*.

ALBERT SAUVEUR, *Vice-Chairman*.

AUGUSTUS H. EUSTIS, *Secretary-Treasurer*, 131 State St., Boston, Mass.

TIMOTHY W. SPRAGUE.

HENRY A. WENTWORTH.

The fourteenth meeting of the Boston Local Section was held at the Engineers' Club, 2 Commonwealth Avenue, Monday evening, November 3. There were 18 members present.

The Chairman, Robert H. Richards, presided at the dinner.

At the close of the dinner, A. H. Eustis spoke informally about his recent trip to the pyrites mining region of southwestern Spain, and showed photographs of the ore docks and open cuts of some of the mines.

AUGUSTUS H. EUSTIS, *Secretary*.



THIRTY REGULAR MEETING OF THE COLORADO LOCAL SECTIONS.

## COLORADO LOCAL SECTION.

*Executive Committee.*WILLIAM J. COX, *Chairman.*CHARLES J. MOORE, *Vice-Chairman.*C. LORIMER COLBURN, *Secretary-Treasurer,*  
614 Ideal Building, Denver, Colo.

THOMAS B. STEARNS.

RICHARD A. PARKER.

*History of the Organization.*

Upon the call of David W. Brunton and John Wellington Finch a meeting of the Colorado members of the American Institute of Mining Engineers was held in the University Club in Denver, in the latter part of 1912. The advisability of organizing a Colorado Section was discussed and a committee of ten men was selected to further consider the organization. Several meetings were held by this committee where the organization was discussed.

On May 15, 1913, a luncheon was given at the Albany Hotel, at which time it was decided to organize a Colorado Section. A committee consisting of Dr. Victor C. Alderson as Chairman, S. A. Ionides, Ernest Le Neve Foster, Charles J. Moore, and Fred. H. Bostwick was appointed to draft the By-Laws and complete the organization.

May 28 the committee met at Mr. Brunton's office, drafted the By-Laws and sent them to New York for approval. They were approved by the Board of Directors of the Institute.

The committee then called the Colorado members of the Institute to attend a luncheon at the Adams Hotel on Sept. 16, complimentary to Mr. Bradley Stoughton, and to act upon the report of the Organization Committee. At this meeting the By-Laws were adopted, and the Colorado Section was permanently organized.

The Chair called for the report of the Nominating Committee. Mr. Ionides reported the following nominations: William J. Cox, Chairman; Charles J. Moore, Vice-Chairman; C. Lorimer Colburn, Secretary-Treasurer. The above members, together with Thomas B. Stearns and Richard A. Parker, to constitute the Executive Committee. These men were unanimously elected, which completed the organization of the Colorado Section. The meeting then adjourned.

*Meeting Nov. 7, 1913.*

Fifty-five members and guests attended the dinner and meeting held in the Palm Room, Brown Palace Hotel, on Nov. 7, 1913. After a very enjoyable and delicious meal the chairman, William J. Cox, called the meeting to order. The History of the Organization of the Colorado Section, the minutes of the meeting of Sept. 16, and the minutes of the meeting of the Executive Committee Oct. 1, 1913, were read and approved. The Secretary-Treasurer reported that the budget presented to the Board of Directors of the Institute had been approved.

The subject for the evening's discussion was The Effect of the Present Methods of Taxing Mines on the Mining Industry of Colorado. The discussion was led by William V. Hodges, who gave a very interesting and instructive talk upon the whole method of taxation. Dan L. Webb then gave a very elaborate discussion of the present methods of taxing mines. He was followed by short discussions from Thomas B. Stearns, Philip Argall, Richard A. Parker, Victor C. Alderson, J. D. Hawkins, Ernest Le Neve Foster, David W. Brunton, Charles J. Moore, and Lyman P. Hammond. The meeting then adjourned.

WILLIAM J. COX, *Chairman.*  
C. L. COLBURN, *Secretary.*

## PUGET SOUND LOCAL SECTION.

### *Executive Committee.*

JOSEPH DANIELS, *Chairman.*

J. N. POTT, *Vice-Chairman.*

I. F. LAUCKS, *Secretary-Treasurer,*

95 Yesler Way, Seattle, Wash.

A. F. BLAIR.

CHESTER F. LEE.

The Puget Sound Local Section held its annual meeting on Saturday, Nov. 1, at the College Club, Seattle, and elected the following men to serve for the ensuing year: Chairman, Joseph Daniels, College of Mines, University of Washington; Vice-Chairman, J. N. Pott, Northwestern Improvement Co., Tacoma; Secretary-Treasurer, I. F. Laucks, of Falkenburg & Laucks, 95 Yesler Way, Seattle; Directors, Chester F. Lee and A. F. Blair, both of Seattle.

J. L. McPherson, Secretary of the Alaska Bureau of the Seattle Chamber of Commerce, a civil engineer, who has been actively identified with engineering work in Alaska since early pioneer days, presented an illustrated talk on Alaska, showing the varied possibilities and developments of Alaska, not only from a mining, but from an agricultural and a fishing standpoint. Photographs of many of the places visited during the excursion recently conducted by the Seattle Chamber of Commerce were shown on the screen.

Plans are being discussed for a series of interesting meetings dealing with topics of particular interest to the mining men of the Northwest.

JOSEPH DANIELS, *Secretary.*

## MANUSCRIPTS RECEIVED BY THE SECRETARY.

The following papers have been accepted for publication in the *Bulletin*. The list is here published in order that application may be made, if desired, for one or more of these papers for discussion by Local Sections of the Institute. Whether these papers are or are not discussed by Local Sections, they will be presented at the February meeting of the Institute in New York, N. Y., and advance discussion by individuals is requested.

Copper Smelting in Japan, by Manuel Eissler.

The Equilibrium Diagram of the System  $\text{Cu}_2\text{S}-\text{Ni}_3\text{S}_2$ , by Carle R. Hayward.

The Mill and Metallurgical Practice of the Nipissing Mining Co., Ltd., by James Johnston.

The Need of Uniform Methods of Sampling Lake Superior Iron Ore, by C. B. Murray.

The Work of Crushing, by Arthur F. Taggart.

## AFFILIATED STUDENT SOCIETIES.

Any society of undergraduates at a technical school, comprising students in any branch of engineering, metallurgy, chemistry, geology, etc., may be recognized by the Board of Directors in its discretion as an Affiliated Student Society. A circular giving details of the plan of affiliation may be obtained on application to the office of the Secretary of the Institute.

The following societies have been placed by authority of the Board of Directors on the above list:

## AFFILIATED STUDENT SOCIETIES.

The Mining Society of the Sheffield Scientific School, Yale University, New Haven, Conn. *President*, ———; *Secretary*, ———.

The University of Illinois Student Branch of the American Institute of Mining Engineers, Urbana, Ill. *President*, M. L. Nebel; *Secretary*, Willis Leriche.

The Engineering Society of the University of Nevada, Reno, Nev. *President*, P. E. Raymond; *Secretary*, R. M. Seaton.

The University of Wisconsin Mining Club, Madison, Wis. *President*, Rudolph J. Stengl; *Secretary*, Mack C. Lake.

The Mining and Geological Society of Lehigh University, South Bethlehem, Pa. *President*, Robert C. Mickel; *Secretary*, Edward B. Snyder.

The School of Mines Society of the University of Minnesota, Minneapolis, Minn. *President*, C. A. Walker; *Secretary*, A. C. Bierman.

The Mining Engineering Society of the Massachusetts Institute of Technology. *President*, Ralph E. Wells, Jr.; *Secretary*, Louis W. Currier.

The Student Auxiliary Society of the American Institute of Mining Engineers of the University of Kansas, Lawrence, Kan. *President*, Walter E. Rohrer; *Secretary*, H. R. Brown.

The Associated Miners of the University of Idaho, Moscow, Idaho. *President*, Walter P. Scott; *Secretary*, Bert F. Smith.

The State College of Washington Mining and Geological Society, Pullman, Wash. *President*, John F. Foran; *Secretary*, Thomas C. Puckett.

The Texas Technical Society, School of Mines, University of Texas, Austin, Tex. *President*, G. C. Cartwright; *Secretary*, David S. Alley.

The Ohio State University Student Branch of the American Institute of Mining Engineers, Columbus, Ohio. *President*, Hugh B. Lee; *Secretary*, E. P. Elliott.

The Stanford Geology and Mining Society, Stanford University, Cal. *President*, B. E. Parsons; *Secretary*, E. D. Nolan.

The Senior Mining Society of Columbia University, New York, N. Y. *President*, ———; *Secretary*, ———.

Mining Association of the University of California, Berkeley, Cal. *President*, D. M. Drumbheller, Jr.; *Secretary*, J. B. Orynski.

Tufts College Chemical Society, Tufts College, Mass. *President*, F. D. Whittemore; *Secretary*, E. W. Hays.

University of Washington Mining Society, Seattle, Wash. *President*, L. H. Cogswell; *Secretary*, E. T. Godbe.

Student Branch of the American Institute of Mining Engineers, Iowa State College, Ames, Iowa. *President*, Lyle A. Butler; *Secretary*, A. J. Crawford.

Missouri Mining Association of the Missouri School of Mines, Rolla, Mo. *President*, L. S. Copelin; *Secretary*, L. J. Boucher.

The Pick and Shovel Club of the Case School of Applied Science, Cleveland, Ohio. *President*, M. T. Whelan; *Secretary*, Lloyd A. Collier.

Colorado School of Mines Scientific Society, Golden, Colo. *President*, Alan Kiscock; *Secretary*, George Wilfley.

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Kentucky Mining Society, College of Mines and Metallurgy, University of Kentucky, Lexington, Ky. *President*, Oliver W. Smith; *Secretary*, Charles E. Straub.

Mining Society of Pennsylvania State College, State College, Pa. *President*, Ralph E. Kirk; *Secretary*, Willard M. Lindsey.

## LIBRARY.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

AMERICAN INSTITUTE OF MINING ENGINEERS.

UNITED ENGINEERING SOCIETY.

WILLIAM P. CUTTER, Librarian.

The Library of the above-named Societies is open from 9 A.M. to 9 P.M. on all week-days, except holidays, from September 1 to June 30, and from 9 A.M. to 6 P.M. during July and August. The Library contains about 55,000 volumes, including sets of technical periodicals and the publications of scientific and technical societies.

Members of the Institute, with few exceptions, are forced to spend a portion of their time in localities isolated from sources of information. To these the Library can render valuable service through correspondence; letters requesting information will receive special attention. The Library is prepared to furnish references and copies of articles on mining and metallurgical subjects; to determine the existence of mining-maps, and to furnish general information as to the geology and mineral resources of all countries.

All communications should be made as definite as possible so that the information received may be what is desired and not include collateral matter which may not be of interest. The time spent in searching for such collateral matter will be saved, and the information will be sent more promptly and in more usable shape.

The members of the Institute can be of service to the Library by forwarding copies of mining-reports, maps privately issued, and similar material, which will be classified, indexed, and made available to other members. Suggestions for additions to the Library, either by purchase or personal solicitation as gifts, will be welcomed. It is hoped that members while in the city will use the Library freely, and assurance is given that most careful service will be rendered to them.

## LIBRARY ACCESSIONS.

### New Books on Mining and Metallurgy.

APPROXIMATE MELTING POINTS OF SOME COMMERCIAL COPPER ALLOYS. Technical Paper No. 60, U. S. Bureau of Mines. Washington, 1913.

CYANIDE PRACTICE 1910-1913. Edited by M. W. von Bernewitz. San Francisco, 1913. (*Gift of Mining and Scientific Press.*)

[NOTE.—This is the third of a series of books that began with "Recent Cyanide Practice" by T. A. Rickard, 1907, and which was continued by "More Recent Cyanide Practice," edited by H. F. Bain and published in 1910. The papers are largely reprints from the *Mining and Scientific Press*.—W. P. C.]

PRINCIPLES AND PRACTICE OF IRON AND STEEL MANUFACTURE. Ed. 3. By Walter MacFarlane. New York, 1912.

METALLURGICAL ANALYSIS, ED. 3. By N. W. Lord and D. J. Demorest. New York, 1913.

FILTERN UND PRESSEN ZUM TRENNEN VON FLÜSSIGKEITEN UND FESTEN STOFFEN. By F. A. Bühler. Leipzig, 1912.

**DIE ABHITZKESEL.** Eine Darstellung der Dampferzeugung mittels Abwärme von Ofen und Hochofengichtgasen. By F. Peter. Wilhelm Knapp, Halle, 1913. Price 8 Marks. (Gift of Publisher.)

[NOTE.—The utilization of the heat of furnace gases is thoroughly treated, description of various existing boiler installations being given, as well as feed-water heaters and superheaters using the waste heat of gases.—W. P. C.]

**FIRST-AID INSTRUCTIONS FOR MINERS.** Miners' Circular No. 8, U. S. Bureau of Mines. Washington, 1913.

**MINE SURVEYING.** By E. B. Durham. McGraw-Hill Book Co., New York, 1913. Price \$3.50. (Gift of Publisher.)

[NOTE.—This is a book on mine surveying, having little on general surveying, and eliminating the usual description of instruments. The author is on the faculty of the University of California.—W. P. C.]

**MISCHEN RÜHREN, KNETEN UND DIE DAZU VERWENDETEN MASCHINEN.** By Hermann Fischer. Leipzig, 1911.

**VERDAMPFEN UND VERKOCHEN.** By W. Greiner. Leipzig, 1912.

### New Books on Geology and Mineral Production.

**ALGUNAS FAUNAS DEL CRETACICO SUPERIOR DE COAHUILA Y REGIONES LIMITROFAS.** By Emilio Bosa. (Boletín del Instituto Geológico de Mexico, No. 30.) Mexico, 1913.

**AUSTRALIA, BULL. No. 18, JUNE, 1913, COMMONWEALTH BUREAU OF CENSUS AND STATISTICS.** Appendix to Monthly Summary of Australian Statistics. Also Monthly Summary, Bull. No. 19, July, 1913. (Gift of *Engineering and Mining Journal*.)

**CALIFORNIA MINERAL PRODUCTION FOR 1912.** Bull. No. 65, California State Mining Bureau. Sacramento, 1913.

**DESCRIPTIVE CATALOGUE OF THE MARINE REPTILES OF THE OXFORD CLAY.** Part II. By C. W. Andrews. London, 1913. (Gift of the British Museum.)

**MINERAL DEPOSITS.** By Waldemar Lindgren. New York, 1913.

**NEW ZEALAND.** Mines Statement, 1912. Mines Department, Wellington, 1913.

### New Books on Non-Metallic Minerals.

**CARBONIZATION OF COAL.** By V. B. Lewes. New York, 1912.

**FULLER'S EARTH.** Bull. No. 71, U. S. Bureau of Mines. Washington, 1913.

**LABORATORY STUDY OF THE INFLAMMABILITY OF COAL DUST.** Bull. No. 50, U. S. Bureau of Mines. Washington, 1913.

**NON-METALLIC MINERALS, THEIR OCCURRENCE AND USES.** Ed. 2. By G. P. Merrill. New York, 1910.

**POSSIBLE CAUSES OF THE DECLINE OF OIL WELLS AND SUGGESTED METHODS OF PROLONGING YIELD.** Technical Paper No. 51, U. S. Bureau of Mines. Washington, 1913.

### New Books on General Subjects.

**DICTIONNAIRE ALLEMAND-FRANCAIS ET FRANCAIS-ALLEMAND DES TERMES ET LOCUTIONS SCIENTIFIQUES.** By R. Cornubert. Paris, 1913.

**MINEING WORLD INDEX OF CURRENT LITERATURE.** Vol. III, 1913. Chicago, Mining World Co., 1913. (Gift of Publisher.)

**O'HARRA'S HANDBOOK OF THE BLACK HILLS.** By C. C. O'Harra. Rapid City, Black Hills Handbook Co., 1913. (Gift of Publisher.)

**POCKET COMPANION FOR ENGINEERS, ARCHITECTS AND BUILDERS.** Containing useful information and tables appertaining to the use of steel. Carnegie Steel Co., Pittsburg, 1913. (Gift of Carnegie Steel Co.)

**STATISTICS OF THE AMERICAN AND FOREIGN IRON TRADES FOR 1912.** Annual Statistical Report of the Bureau of Statistics, 1913. American Iron and Steel Institute, Philadelphia, 1913.

## Company Reports.

(GIFT OF KIRBY THOMAS.)

- ARIZONA UNITED MINING Co. Report of J. M. Libbey, Mine Manager, 1912. Philadelphia, n. d.  
 — Annual Report, 1912. Philadelphia, n. d.  
 BLACK HILLS CONSOLIDATED MINES. Perpendicular view of the Homestake veins and strike of ledges. Lead, S. D., n. d.  
 BOULDER MINING & DEVELOPMENT Co. Montana Group of Mines. Philipsburg, n. d.  
 BRUCE MINES AND ALGOMA RAILWAY. Plan showing probable route of proposed extension. (Blue print.)  
 CARIBOU COBALT MINES Co. Description of. N. p., n. d.  
 CHAMPS D'OR RIGAUD VAUDREUIL, LTD. Nuggets. Montreal, n. d.  
 EMPIRE COPPER & GOLD MINING Co. Description. Los Angeles, n. d.  
 — A Wireless Message. Los Angeles, n. d.  
 FEDERAL CHEMICAL Co. Improved new process rock. Louisville, n. d.  
 GARDNER MOUNTAIN GOLD PROPERTY, NEW HAMPSHIRE. Report, 1913.  
 INSPIRATION COPPER Co. Annual Report, 1st, 1910.  
 LAKE HURON & NORTHERN ONTARIO RAILWAY Co. Description. N. p., 1913.  
 MARYSVILLE GOLD MINING Co. Property of, with map.  
 MENES MINES, LTD. Prospectus. N. p., n. d.  
 MINES COMPANY OF AMERICA. Annual Report, 1910. New York, 1910.  
 MUTUAL MINING & LEASING Co. OF ARIZONA. Underwriting. N. p., n. d.  
 NORTH, F. A. A Corporation Handbook. Merchants Edition. Boston, n. d.  
 SAN JUAN EXPLORATION Co. Description. Washington, n. d.  
 SUPERIOR & BOSTON COPPER MINING Co. Pre-Historic Copper Mining.  
 TEMISKAMING MINING Co., LTD. Annual Report, 6th, 1912.  
 THOMPSON, TOWLE & Co. Production, estimated earnings and dividends of the important copper mines of the United States, Mexico and Canada. N. d.  
 VANADIUM QUEEN MINING Co. Description of property. N. p., n. d.

## Trade Catalogues.

- AMERICAN DIRECT CONCENTRATING Co., Salt Lake City, Utah. Bull. A. Tube concentrators. Sept., 1911.  
 CHICAGO PNEUMATIC TOOL Co., Chicago, Ill. Bull. No. 34-D. "Chicago Pneumatic" Corliss compressors, steam-driven. Oct., 1913.  
 COLORADO MACHINERY & SUPPLY Co., Denver, Colo. Stock list No. 8, 1913. New and second-hand machinery.  
 DEISTER CONCENTRATOR Co., Fort Wayne, Ind. Catalogue of Ore Concentrators. Sept., 1913.  
 D. D. DEMAREST Co., San Francisco, Cal.  
 Circular No. 27. Pacific Steam Guides. Nov., 1911.  
 Circular No. 28. Pacific Lubricating Stop Cock. Dec., 1909.  
 Circular No. 30. Pacific Rock Drills. June, 1910.  
 Circular No. 33. Neilsen Pumps. Dec., 1910.  
 FORT WAYNE ELECTRIC WORKS, Fort Wayne, Ind. Bull. 1143. Fort Wayne Electric Rock Drill, type "A." June, 1912.  
 GENERAL ELECTRIC Co., Schenectady, New York.  
 Bull. A 4131. Storage battery industrial and mining locomotives. Oct., 1913.  
 Bull. A 4151. Engine-driven continuous-current generators. Oct., 1913.  
 GLOBE IRON WORKS, San Francisco, Cal. Catalogue No. 2. Truax Automatic ore cars. 1905.  
 GOLDEN-ANDERSON VALVE SPECIALTY Co., Pittsburg, Pa. Circular of automatic cushioned steam and water service valves.



INGERSOLL-RAND Co., New York, N. Y.

Circular on "Imperial" electric driven compressors.

A few remarks about Calyx core drills.

KNOX AUTOMOBILE Co., Springfield, Mass. Description of Knox Martin Tractor. 27 pp.

LESCHEN, A. & SONS ROPE Co., St. Louis, Mo. Leschen's Hercules. Nov., 1913.

S. MORGAN-SMITH Co., York, Pa. Bull. No. 104. Smith Turbines. March, 1913.

RISDON IRON WORKS, San Francisco, Cal.

Catalogue No. 12, Ed. 4. Gold milling machinery.

Catalogue No. 14, Ed. 5. Risdon-Johnston concentrator.

Catalogue No. 8, Ed. 2. Bryan Roller Quartz Mill.

Catalogue No. 17, Ed. 7. Gold Dredging Machinery.

ROEBLING'S, JOHN A. SONS Co., Trenton, N. J. Wire rope at Panama.

SALT LAKE HARDWARE Co., Salt Lake City, Utah. Catalogue No. 1. Machinery.

SANFORD-DAY IRON WORKS, Knoxville, Tenn. Wheelology. Oct., 1913.

SULLIVAN MACHINERY Co., Chicago, Ill. Bull. 58-L, Ed. 2. Air-compressor accessories. Oct., 1913.

UNITED METAL HOSE Co., New York, N. Y. Catalogue describing different kinds of hose. N. d.

UNION IRON WORKS Co., San Francisco, Cal.

Bull. No. 1. Union improved mine safety crosshead. May, 1907.

Catalogue No. 5, Evans hydraulic elevators and hydraulic mining machinery.

Blake and Dodge rock breakers.

California stamp mill. 70 pp.

WORD BROS., San Francisco, Cal.

Drill Sharpener Book.

Drill Maker and Sharpener.

Drill Sharpener, Chain Drive Type. July, 1912. (Blueprint.)

Improved oil forge. (Blueprint.)

## MEMBERSHIP.

### NEW MEMBERS.

The following list comprises the names of those persons who became members during the month of November, 1913:

#### *Members.*

|                                                                                         |                                            |
|-----------------------------------------------------------------------------------------|--------------------------------------------|
| AGNEW, JOHN L., Genl. Supt.....                                                         | Copper Cliff, Ont., Canada.                |
| BAILEY, FRANK C., Mine Mgr.....                                                         | 2903 W. Suito Ave., Spokane, Wash.         |
| BATEMAN, ALAN M., Min. Geol., Care L. C. Graton, Geological Museum, Cambridge, Mass.    |                                            |
| BERRYHILL, JAMES G., Atty.-at-law and Mining Investor, Equitable Bldg., Des Moines, Ia. |                                            |
| CARTLIDGE, OSCAR, Mgr. State Mine Rescue Station,                                       | 452 W. South Grand Ave., Springfield, Ill. |
| CHAPMAN, IRVING A., Miner.....                                                          | Leonard Hotel, Butte, Mont.                |
| CLAGHOEN, JAMES L., Min. Engr.....                                                      | Tacoma, Wash.                              |
| CONGDON, EDWARD C., Mining.....                                                         | 807 Lonsdale Bldg., Duluth, Minn.          |
| CREDEN, WILLIAM I., Min. Engr.....                                                      | First National Bank Bldg., Butte, Mont.    |
| ERNEST, RICHARD H., Min. Engr.....                                                      | Round Mountain, Nev.                       |
| FRANKE, ROBERT, Min. Engr.....                                                          | P. O. Box 100, Miami, Ariz.                |
| GALLOWAY, ALAN D. R., Min. and Met. Engr.....                                           | La Paz, Bolivia, So. America.              |
| GORDON, ROBERT, Mine Supt. .                                                            | Montezuma, Costa Rica, C. A.               |
| HARMON, ALBIN K. P., Geol.....                                                          | 822 Mills Bldg., San Francisco, Cal.       |
| HERRON, JAMES H., Cons. Met. Engr.....                                                  | 2041 E. 3d Street, Cleveland, Ohio.        |
| HOFFMANN, ROSS E., Min. Engr.....                                                       | 228 Perry St., Oakland, Cal.               |
| JOHNSON, CLIFTON B., Construction.....                                                  | El Paso Smelting Wks., El Paso, Texas.     |
| JONES, THOMAS R., Mgr.....                                                              | Buffalo Mine, Cobalt, Ont., Canada.        |
| JONES, WILLIAM W., N. Y. State Mine Inspector.....                                      | Dept. of Labor, Albany, N. Y.              |

|                                                                                       |                                                    |
|---------------------------------------------------------------------------------------|----------------------------------------------------|
| LACHMUND, OSCAR, Min. Engr.....                                                       | Greenwood, B. C., Canada.                          |
| LESLIE, EUGENE H., Asst. Editor, <i>Mining and Scientific Press</i> , 420 Market St., | San Francisco, Cal.                                |
| McNUTT, VACHEL H., Geol. and Min. Engr.....                                           | 318 Clinton Building, Tulsa, Okla.                 |
| MEIKLEJOHN, DAVID F., Min. Engr.....                                                  | 50 Pastita, Guanajuato, Mexico.                    |
| MILLER, DONALD C., Min. Engr.....                                                     | Tyrone, N. M.                                      |
| NORRIS, EDWARD M., Min. Engr.....                                                     | P. O. Box 470, Butte, Mont.                        |
| PIERCE, FREDERIC E., Chief Engr., New Jersey Zinc Co., 55 Wall St., New York, N. Y.   |                                                    |
| PRINDLE, EDWIN J., Patent Attorney.....                                               | 111 Broadway, New York, N. Y.                      |
| REA, JOHN E., Min. Engr.....                                                          | W. 25 7th Ave., Spokane, Wash.                     |
| SIVYER, LEONARD, D., Min. Engr.....                                                   | 2135 Second Ave., Los Angeles, Cal.                |
| STODDARD, JESSE C., Min. Engr.....                                                    | Empire Steel & Iron Co., Mt. Hope, Wharton, N. J.  |
| STONE, C. J., Supt. of Mine.....                                                      | P. O. Box 4, Butte, Mont.                          |
| TROUTMAN, JOHN H., Genl. Mgr.....                                                     | Empire Zinc Co., 703 Symmes Bldg., Denver, Colo.   |
| WEAVER, ALFRED H., Min. Engr.....                                                     | Spanish-American Iron Co., Santiago-de-Cuba, Cuba. |
| WILLIAMS, HERBERT L., Met. Engr.....                                                  | 730 First National Bank Bldg., Denver, Colo.       |
| WINNE, ROLLO D., Deputy Mine Inspector.....                                           | P. O. Box 894, Crystal Falls, Mich.                |

### *Honorary Members.*

|                                                                  |                                                             |
|------------------------------------------------------------------|-------------------------------------------------------------|
| ADAMS, DR. FRANK DAWSON, Logan Prof. of Geology, and Dean of the | Faculty of Applied Science, McGill Univ., Montreal, Canada. |
| ORDOÑEZ, EZEQUIEL.....                                           | Mexico City, Mexico.                                        |

### *Associate.*

|                               |                |
|-------------------------------|----------------|
| SMITH, ARTHUR, Genl. Mgr..... | East Ely, Nev. |
|-------------------------------|----------------|

### *Junior Members.*

|                                         |                                                   |
|-----------------------------------------|---------------------------------------------------|
| HORCASITAS, AUGUSTIN S., Min. Engr..... | Maxwell Land Grant Co., Baldy, N. M.              |
| LEONARD, HARRY R., Min. Engr.....       | Spanish-American Iron Co., Felton, Oriente, Cuba. |
| SCOOLES, JOHN C., Student.....          | Univ. of Wis., Granton, Wis.                      |
| SLATER, JOHN L., JR., Assayer.....      | 2933 Lincoln Ave., Alameda, Cal.                  |

### CANDIDATES FOR MEMBERSHIP.

The following persons have been proposed during the month of November, 1913, for election as members of the Institute. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Board of Directors, which has the power of final election.

### *Members.*

**Frank H. Bird, Spokane, Wash.**

Proposed by L. K. Armstrong, Charles H. Goodsell, J. Edward Rea.

Born, 1861, New Haven, Conn. City Schools, New Haven, Conn. 1879, Henry Killam Co., New Haven, Conn. 1881, New Haven Tool Co. 1884, Sargent Co., New Haven, Conn. 1886-96, Allis-Chalmers Co., Chicago, Ill. 1896-1900, Kinnie Manfg. Co., Minneapolis, Minn. 1900-02, Killgore Manfg. Co., Minneapolis, Minn. 1906, Fairbanks-Morse Co., Spokane, Wash. 1907, Bradley Engineering Co., Spokane, Wash. 1907-08, Sullivan Smelter, Marysville, B. C. 1908-12, Corrigan-McKinney Co., Terrazas, Mex. 1913, Practice, Spokane, Wash.

Present position: Construction Engineer.

**Henry N. Baumann, Jr., Chichagof, Alaska.**

Proposed by Milnor Roberts, Joseph Daniels, Henry Landes.

Born, 1888, Sacramento, Cal. 1906, Grad. Seattle High School. 1911, Grad. College of Mines, University of Washington; B. S. degree. Summers 1907-08, Snowstorm & Standard Mines, Mace, Idaho; Smelter construction, Bunker Hill M. & S. Co., Reiter, Wash. 1911, Assayer and draftman, Rohlf & Soule, Mining Engrs., Valdez, Alaska. 1912, Chichagof Mining Co., Chichagof, Alaska.

Present position: Amalgamator.

**Frank Cleveland Blickensderfer, Morenci, Ariz.**

Proposed by M. H. McLean, Frank W. McLean, F. H. Hayes.

Born, 1887, Canal Dover, Ohio. 1907-11, Ohio State University School of Mines; degree Engineer of Mines. 1905-07, Penn. Iron & Coal Co., pig iron blast furnace, Canal Dover, Ohio. 1911-12, Assayer, Detroit Copper Mining Co., Morenci, Ariz. 1912, Shift Foreman, Leaching Plant, Mexicana Metallurgical Co. 1912-13, Assayer and Sampler, Detroit Copper Mining Co., Morenci, Ariz.

Present position: Sampler in concentrator of Detroit Copper Mining Co., Morenci, Ariz.

**Burt Boynton Brewster, St. Louis, Mo.**

Proposed by H. O. Mercer, F. L. Van Orden, W. E. Hopper.

Born, 1890, Brussels, Belgium. 1898-1902, Schools in New York City. 1902-03, Private Tutorship. 1903-08, Smith Academy, Wash. University, St. Louis, Mo. 1908-12, Michigan College of Mines, 1911-12, Engr. for Willis Coal & Mining Co. and Columbia Quarries Co., St. Louis. 1912, Sales Engineer, Sullivan Co., St. Louis, Mo.

Present position: Sales Engineer, St. Louis, Durson-Sullivan Mch. Co.

**Henry Oliver Coles, Bisbee, Ariz.**

Proposed by R. R. Goodrich, A. L. Waters, H. B. Goodrich.

Born, 1887, Chicago, Ill. 1913, Degree B. S. Mining Engineering, University of Ariz., four years C. & A. and C. Q. mines, Bisbee, Ariz. 1912, Filter plant operator, El Tigre, Mexico.

Present position: Assayer Copper Queen Min. Co., Ariz.

**Hilton H. Colley, Douglas, Ariz.**

Proposed by Forest Rutherford, Harold O. Hammond, Gerald Sherman.

Born, 1875, England. 1898-1901, Technical Chemistry and Metallurgy at Rolla School of Mines, Mo. 1898-1901, Assayer for Kansas City Consolidated Smelting & Refining Co. 1902-04, Head Chemist and Assayer for Penns. Western Smelter Co., Kansas. 1904, Foreman for Waihi Gold Mining Co., N. Z. 1905, Chemist for Mineral Point Zinc Co., North Chicago. 1905-07, Assayer for Copper Queen Consolidated Mining Co. 1905-13, Asst. Supt., Copper Queen Consolidated Mining Co., Douglas, Ariz.

Present position: Asst. Metallurgist, Copper Queen Cons. Mining Co.

**A. W. Dickinson, Bevier, Mo.**

Proposed by F. W. McNair, William Kelly, F. L. Van Orden.

Born, 1886, Highland Park, Ill. 1903, Grad. Englewood High School, Chicago. 1905-08, Michigan College of Mines; degree E. M. 1908, Asst. Engr. C. C. & C. Co., Pittsburg, Kan. 1910, Res. Engr. C. C. & C. Co., Bevier, Mo. 1911, Dist. Supt., C. C. & C. Co. 1903, Roustabout, C. B. Smith, R. R. Contractor, Tenn. and Miss. 1904, Mule Driver, Batson Prairie Oilfield, Tex.; Timekeeper, United Oil & Refining Co., Beaumont, Texas; pumper and oil tester for same firm. 1904-05, Armour Packing Co., Chicago. Summer 1905-08, Timberman and Machine helper, Baltic Mine, Copper Range Cons., Baltic, Mich. 1908 to date, Lead and Zinc Co., Platteville, Wis.

Present position: Dist. Supt., Central Coal & Coke Co., Kansas City, Mo.

**Fletcher Gardner Downs, 312 Calle Washington, Montevideo, Uruguay, S. A.**

Proposed by Mortimer L. Lee, Thomas T. Read, G. H. Hooper.

Born, 1885, Jersey City, N. J. 1906, Degree Bachelor of Arts, Columbia University, N. Y. 1908, Degree of Engineer of Mines, Columbia School of Mines, N. Y. 1908-09, Asst. to Mgr., Fixico Mining Co., Fixico, Ala. 1911-12, Assayer and bookkeeper for Eustis Mining Co., Eustis, Quebec, Canada.

Present position: Surveyor for Inst. de Geologia y Perforaciones, Uruguayan government.

**Alfred Winter Evans, Reefton, New Zealand.**

Proposed by Thomas T. Read, J. F. Kemp, Charles Berkey.

Born, 1881, Natal, So. Africa. 1893, Durban High School, So. Africa. 1893-98, St. George's School, Harpenden Hts., Eng. 1902-06, Columbia University, N. Y.; degree

**E. M.** 1898-99, Crown Deep G. M. Co., Johannesburg. 1899-1902, Boer War. 1906, Assayer to Mining Co., Poland, Ariz. 1907-08, Underground contractor, So. African Mines, French Rand G. M. Co., Village Haih Reef City Deep, Ferrerra G. M. Co., Johannesburg. 1909, G. Mgr., Consolidated Goldfields of N. Zld. 1910-11, Asst. Gen'l Mgr. Simmer Deep G. M. Co., Johannesburg.

Present position: Genl. Mgr. and Consulting Engr., Consolidated Goldfields of New Zealand, Ltd., Reefton, N. Z.

**Arthur Ransford Fletcher**, El Callao, Venezuela.

Proposed by J. F. Kemp, Charles Berkey, W. M. Drury.

Born, 1883, Ogden, Utah. 1902-07, Leland Stanford University; Bachelor of Arts. 1909-11, Columbia University; Engineer of Mines. 1905, Patent Surveyor, U. S. Dep. Min. Surveyor. 1907-09, Aid U. S. Coast and Geodetic Survey, Philippine Islands. 1911-12, Geological and reporting work for W. Rowland Cox, Canada, U. S. and Mexico. 1912-13, American Smelters Securities Co., Santa Barbara; Supt. at Villa Escobedo, Mexico.

Present position: Mining Engineer with Campagne Ferniere des Mines d'Or d'El Dorado, Venezuela.

**Charles N. Forrest**, Maurer, N. J.

Proposed by Anthony F. Lucas, C. T. Day, Samuel Whinery.

Born, 1873, Baltimore, Md. Public Schools, Baltimore Polytechnic, Maryland Institute. 1886, Chemical instruction as special student Columbian University, Washington, D. C. 1892, Asst. in Chem. and Phys. Laboratories, Baltimore & Ohio R. R., Baltimore, Md. 1896-97, Asst. Chem. Southern Ry., Washington, D. C. 1897-1904, Chemist and Inspector, L. I. R. R., L. I. City, N. Y.

Present position: 1904 to date, Chief Chemist, New York Testing laboratory.

**Everett Lawrence Fraser**, Allegheny, Cal.

Proposed by E. Howe, William Hague, A. D. Foote.

Born, 1881, Hudson, Mass. 1899, College in Boston. 1906, Big Canyon Mine, Cal. 1907, Odell Wilson, Cleveland. 1908-12, W. P. Hammon, San Francisco, Mine Sampler, Assayer, Mine and Mill foreman, Asst. Supt. 1912, Tightner Mine Co., Allegheny, Cal.

Present position: Mill Supt. Tightner Mine Co.

**Albert W. Frolli**, 216 N. Main St., Salinas, Cal.

Proposed by H. W. Young, G. H. Clevenger, D. M. Folsom.

Born, 1885, Salinas, Cal. 1905-09, Stanford Univ.; A. B. 1910, Surveyor and Draftsman, L. G. Hare, Tecopa Mining Co., Tecopa, Cal. 1911, Geologist, R. T. Hill, Mexico; Concentratorman, Ray Copper Co., Ariz.; Concentratorman, Miami Copper Co., Ariz.; Churn Drill Sampler, Inspiration Copper Co., Ariz.; Cyanide Foreman, Vulture Mine Co., Ariz.

Present position: 1911 to date, Examining Engineer, Babiloma Gold Mines, Ltd., Nicaragua, C. A.

**A. Stanley Hill**, Gem, Idaho.

Proposed by James F. McCarthy, W. J. Hall, Rush J. White.

Born, 1888, Minneapolis, Minn. 1906, Central High School, Minneapolis. 1911, Grad. School Mines, University of Minnesota; E. M. 1909, Hecla Mine, Burke, Idaho. 1911-12, Lake Superior Corp., Ontario, Canada; Engineer Maggie Mine, Supt. of diamond drill exploration.

Present position: Assayer, Hecla Mining Co., Gem, Idaho.

**Hugh Gerald Hilton**, Erie, Pa.

Proposed by Edward B. Cook, James Gayley.

Born, 1889, Strathroy, Ont. 1910, B. S., Case School of Applied Science. Summers 1907-08-09, Champion Copper Co., Painesdale, Mich.; Oliver Iron Mining Co., Coleraine, Minn., Homestake Mining Co., Lead, S. D. 1910-13, Federal Furnace Co., So. Chicago, Ill.

Present position: General Foreman Penn. Iron Co., Erie, Pa.

**George J. Lyon**, Schenectady, N. Y.

Proposed by Thomas T. Read, Fred. Crabtree, C. T. Griswold.

Born, 1874, New York City. Public Schools of New York. 1899, B. S. degree, University of Nebraska. 1904, Civil Engineer, Columbia University. 1899-1902, Railroad experience on location, construction and maintenance with Union Pacific, New York Central and New York, Ontario & Western Railroads. 1904-10, Prof. of Civil Engineering,

Colorado Springs. 1900 to date, Asst. Prof. Civil Engineering, Union College, in charge of hydraulics, water supply, sanitary engineering; Asst. engineer U. S. Geological Survey, Denver and New York districts. 1904 to date, Consulting Engineer.

Present position: Asst. Engineer, U. S. Geological Survey; Asst. Prof. Civil Engineering, Union College; Consulting Engineer.

**Newton C. Marshall**, Winona, Mich.

Proposed by R. R. Seeber, A. L. Dickerman, Charles F. Rand.

Born, 1888, Milwaukee, Wis. 1908-11, Engineering Dept., University of Michigan. 1911-13, Michigan College of Mines; degree B. S. and E. M. 1906-08, Draftsman, Eng. Dept., Chicago, Rock Island & Pacific Ry., Davenport, Iowa. 1909-10, Draftsman, foreman, instrument man, Isthmian Canal Commission and Panama Railroad, Canal Zone. 1913, Instructor in Mine Surveying, Michigan College of Mines; Mining Engineer, Winona Copper Co., Winona, Mich.

**George Bowen Marshall**, Miramor, Costa Rica.

Proposed by H. B. Price, A. E. Keiller, P. G. Spilsbury.

Born, 1879, New York City. Grad. Michigan College of Mines, degree B. S. Grad. N. Y. Public Schools, N. Y. Prep. School. 1907, Transitman; N. Y., N. H. & H. R. R. 1908, Surveyor, Standard Cons. Min. Co., Bodie, Cal.; Sampler, El Oro Min. & R. R. Co., El Oro, Mexico. 1909-10, Shift boss, Cyanide Plants, El Cuba Mine & Mill Co., Mexico. Present position: Engineer, Mine La Union, Panama & Costa Rica Mine Co.

**William J. McGee**, San Francisco, Cal.

Proposed by Thomas T. Read, W. C. Ralston, E. H. Benjamin.

Born, 1873, California. Grad. Law Dept., University of Cal. Actively engaged in quartz mining in Amador County, Cal.

Present position: Asst. Treasurer of the U. S. at San Francisco, Cal.

**Frank Kenyon McIntosh**, Verona, Mich.

Proposed by F. W. Sperr, L. M. Hardenburgh, Stephen Royce.

Born, 1888, Brownsville, Ind. Common and High School, Traverse City. 1911, Mich. College of Mines, Houghton, Mich.; B. S. and Engineer of Mines. 1911, Engineer of Cary Mines, Henley, Wis. 1913, Engineer for Pickands Mather, Gogebic Range.

Present position: Supt. Mikado Mine, Verona, Mich.

**Stanley R. Moore**, Wallace, Idaho.

Proposed by W. J. Hall, Francis A. Thomson, L. K. Armstrong, O. B. Hofstrand.

Born, 1877, Republic, Ohio. 1900-04, course in Mining Engineering Univ. of Missouri; degree B. S. and E. M. 1904-05, Montana Zinc Co., Butte, Mont. 1905-07, Mining Engr. for Silver Fissure Min. Co., Polaris, Mont. 1907-12, General Engineering practice at Wallace, Idaho. 1913, Success Mining Co., Wallace, Idaho.

Present position: Foreman Success Mine.

**Henry H. Otto**, Wilkes-Barre, Pa.

Proposed by Howard Eckfeldt, Paul Sterling, F. W. Chaser.

Born, 1886, Philadelphia, Pa. 1892-1903, Hazelton, Pa., Public Schools and High School. 1907-08, Harry Hillman Academy, Wilkes-Barre, Pa. 1908-12, Lehigh University, So. Bethlehem, Pa.; degree E. M.; Lehigh Valley Coal Co., Mining Engineering Dept. 1901-02-04, Lehigh Valley Coal Co., Wilkes-Barre. 1904-06, Kingston Coal Co. Summers 1908-09, Lehigh Valley Coal Co. Summers 1910-11, U. S. G. Survey, Topographic Aid.

Present position: 1912 to date, Inspector in the Inspection of Equipment Dept., Lehigh Valley Coal Co.

**Ralph R. Parish**, Waterbury, Conn.

Proposed by L. W. Bahney, J. F. McClelland, Joseph W. Roe.

Born, 1885, Portland, Me. 1909, Ph. B., Yale University; Federal Mining & Smelting Co. 1910, La Plata Gold Mining Co. 1911, Chase Rolling Mill Co., Waterbury, Conn.

Present position: Chemist for the Chase Rolling Mill Co.

**Floyd W. Parsons**, N. Y. City.

Proposed by Louis D. Huntoon, Kirby Thomas, W. R. Ingalls.

Born, 1880, Keyser, W. Va. 1902, degree E. M., Lehigh Univ., So. Bethlehem, Pa.; Backsight Engineer Corps, Lehigh Valley Coal Co.; advance to district engineer. 1903, Asst. Engr. Cons. Coal Co., Fairmont, W. Va. 1904, Chief Engr., New River Collieries Co., Ruah Run, W. Va. 1905, Instructor of Mining, Mich. College of Mines, Houghton, Mich. 1906, Chief Engr., Victoria-American Fuel Co., Denver, Colo. 1907-11, Associate Ed. *E. and M. Journal*.

Present position: Editor *Coal Age*.

**Curtis Pigott, East Helena, Mont.**

Proposed by Reno H. Sales, F. M. Smith, J. A. Grimes.

Born, 1887, Booneville, Mo. 1905-08, Yale; Ph. B. 1908-10, Columbia School of Mines; degree E. M. 1910-11, Asst. Chemist at East Helena Plant of American Smelting & Refining Co.

Present position: 1911 to date, In charge of Roasters at East Helena Plant.

**Winfield S. Potter, Pittsburg, Pa.**

Proposed by Charles H. White, Albert Sauveur, Herbert M. Boylston.

Born, 1866, Brooklyn, N. Y. 1880-87, Brooklyn Polytechnic; B. S. 1888-90, Rensselaer Polytechnic; C. E. 1890-91, Instructor Rensselaer Poly. 1883-91, Building Construction, St. Paul, Minn., and Birmingham, Ala. 1889-99, Mining, Logging, Farming, Dakotas, Wyoming, Montana, Minnesota. 1899-1904, Steel Foundry, Am. Hoist & Derrick Co., St. Paul; Wm. Wharton, Jr., Phila.; Newport News Shipbuilding & Dry Dock Co.; Am. Brake Shoe & Fdy. Co., Chicago Heights. 1904-08, Iron Founding, American Brake Shoe Co. 1906-12, Manganese Steel Rolling and Forging.

Present position: V. P. Manganese Steel Rail Co., Pres. Alloy Steel Forging Co.

**Henry B. Reed, New York, N. Y.**

Proposed by W. L. Saunders, H. A. Keller, George A. Howells.

Born, 1867, Canton, Ohio. Public Schools and Feller Commercial School of Canton, Ohio. 1884-90, Asst. Engr. Location and construction of portions, Wheeling and Lake Erie; Baltimore & Ohio, Penn. Railroads; Development of coal mining properties. 1890-95, Chief Engr. Ryan & McDonald Cons. Co., building Baltimore & Ohio Railroad tunnels. 1895-1912, Chief Engr. and Genl. Supt. McDonald & Onderdonk, contractors construction of Jerome Park Reservoir and aqueducts, New York City Water Supply; Engr. for J. B. McDonald and the Rapid Transit Subway Construction Co.

Present position: 1909 to date, Pres. Brothers Valley Coal Co., Macdonaldton, Pa.

**Clifford Richardson, New York, N. Y.**

Proposed by David T. Day, Anthony F. Lucas, Thomas T. Read.

Born, 1856, Worcester, Mass. 1877, degree A. B., Harvard Univ.; Student University of Bonn. 1878, Asst. Hayden Geological Survey. 1878-87, Asst. Chemist, U. S. Dept. of Agriculture. 1887-94, Inspector of Asphalt and Cements, Engineer Dept., District of Columbia. 1894-1910, Chemical Engineer in connection with bituminous industries, asphalt pavements, etc.

Present position: 1910 to date, Consulting Chemical Engineer and Expert on Roads and Paving Construction.

**Andrew Rocca, Jr., Larson, Idaho.**

Proposed by L. K. Armstrong, Francis A. Thomson, William J. Hall, O. B. Hofstrand.

Born, 1889, Middletown, Cal. 1910-Jan., 1912, University of California, class of 1914. Jan.-Mar., 1912, Helen Quicksilver Mine, Cal. Mar.-July, 1912, Bunker Hill & Sullivan Mining & Concentrating Co. July, 1912, to date, Snow Storm Mining Co.

Present position: Engineer for the above company.

**Sydney Lathan Shonts, Wallace, Idaho.**

Proposed by Francis A. Thomson, W. J. Hall, L. K. Armstrong, R. J. White.

Born, 1881, Fergus Falls, Minn. 1904, E. M., Minnesota School of Mines. 1904-05, Federal Mining & Smelting Co. 1905-07, Bunker Hill & Sullivan Min. Co. 1907-09, Pittsburg Lead-Mining Co. 1909-11, Bunker Hill & Sullivan Min. Co.

Present position: 1911 to date, private practice.

**Frederick N. Shepard, Franklin Furnace, N. J.**

Proposed by George C. Stone, J. A. Van Mater, William A. Pomeroy.

Born, 1881, So. Orange, N. J. 1902, A. B., Princeton Univ. 1904, E. E., Princeton Univ. 1904-05, Westinghouse Electric & Manufacturing Co., Engineering Apprentice. 1906, N. Y. C. & Hudson River R. R. Co., Electrical Engineering Dept. 1906-10, N. J. Zinc Co., Mill Asst. and Electrical Engr.

Present position: 1910 to date, Mill Supt., The New Jersey Zinc Co., Franklin Mines, Franklin, N. J.

**Frank G. Stantial, Everett, Mass.**

Proposed by Augustus H. Eustis, Robert H. Richards, Charles E. Locke.

Born, 1857, Melrose, Mass. Grad. in Chemistry, S. B., Mass. Institute Technology.

Present position: 1882 to date, Supt. Cockran Chemical Co.

**Forrest M. Towl**, New York, N. Y.

Proposed by D. T. Day, E. W. Parker, Anthony F. Lucas.

Born, 1863, Parma, Ohio. 1879, Grad. Brooklyn Village, Ohio, 'high school. 1886, Grad. Cornell University; degree C. E. 1879-81, Field work. 1881-86, Student Cornell University. 1886-1911, Engineering work with Standard Oil Co. 1911 to date, Pres. Southern Pipe Line Co., The Eureka Pipe Line Co., South West Penna. Pipe Lines, Cumberland Pipe Line Co., Inc.

Present position: President of above companies.

**Andrew Millick Tweedy**, New York, N. Y.

Proposed by Felix A. Vogel, Henry D. Hibbard, Bradley Stoughton.

Born, 1884, Knickerbocker, Texas. 1905-06, Columbia School of Mines; degree E. M. 1900-02, High School, Plainfield, N. J. 1902-03, Princeton, C. E. Dept. 1911-12, Asst. to Mgr. Mining Dept. Cia. Metalurgica Mexicana, Mexico. 1910-11, Asst. Supt. San Pedro Mines, Mexico. 1908-10, Mine Foreman, Montezuma Lead Co., Santa Barbara. 1907-08, Shift boss Sierra Majado Mines, Cia. Meta. Mexa. 1907, Supt. American Pyrites Co., Gouverneur, N. Y. 1906, Engineer, St. Lawrence Pyrites Co., Harmon, N. Y.

Present position: Engineer, General Briquetting Co., Bates Iron Co., Florence Iron Co.

**Ray E. Walters**, Larson, Idaho.

Proposed by W. E. Greenough, L. K. Armstrong, Francis A. Thomson, R. J. White.

Born, 1884, Kansas. 1905, University Montana; A. B. 1910, Columbia University, E. M. 1906, Snow Storm Mining Co., Miner. 1907, Bunker Hill & Sullivan, Miner. 1909, Snow Storm, Miner. 1910, Goldfield Con., Miner. 1911, Snow Storm, Engineer.

Present position: 1912 to date, Asst. Manager, Snow Storm Mining Co., Larson, Idaho.

**John D. Wanvig, Jr.**, Patagonia, Ariz.

Proposed by R. B. Earling, G. H. Morgan, Frank H. Probert.

Born, 1887, Milwaukee, Wis. 1907, B. S., Michigan College of Mines. 1908, E. M., Michigan College of Mines. 1907, Engr. Cole & McDonald Exploration Co., Virginia, Minn. 1908, Engr. Miami Copper Co., Miami, Ariz. 1909, Engr. Superior & Boston Copper Co., Globe, Ariz. 1909-11, Supt. Superior & Boston Copper Co., Globe, Ariz. 1912, Engr. Frank H. Probert, Los Angeles, Cal.

Present position: Supt. Three R. Mines, Patagonia, Ariz.

**George Wellington Waters**, Gatico, Chile.

Proposed by E. P. Mathewson, C. D. Demond, F. F. Frick.

Born, 1860, Newark, N. J. Public Schools in Orange, N. J. 1871-73, Newark Academy. 1874, Burnett St. Grammar School. 1875-76, Newark High School. 1895-98, Charge of the Pocillas Gold Mining Syndicate's Mines at Pocillas, Chile. 1878-85, Edison Co., Electrical Engineer, in the States and Chile. 1907 to date, Chief Engineer and Mgr. Cia. de Minas de Cobre de Gatico, Gatico, Chile. 1883 to date, member of Spencer & Waters, Santiago, Chile. 1908 to date, Associated with F. D. Aller as Ore Purchasing Agent for A. S. & R. Co., in Chile.

Present position: Mgr. of the Cia. de Minas de Cobre de Gatico, Gatico, Chile.

**David White**, Washington, D. C.

Proposed by Anthony F. Lucas, George O. Smith, D. T. Day.

Born, 1862, Palmyra, N. Y. 1886, B. S., Cornell Univ. 1886 to date, U. S. Geological Survey; Honorary connection with Smithsonian Inst.; Personal interest in Fossil Plants and the Geology of Fuels.

Present position: Chief Geologist, U. S. Geological Survey, Washington, D. C.

**James B. White**, Marion, Ky.

Proposed by Reno H. Sales, J. A. Grimes, M. H. Gidel.

Born, Louisville, Ky., 1872. Attended various schools in Louisville. 1887, St. Mary's College, Kansas; degree A. B. 1895, Employed by Anaconda Copper Mining Co., 4 years in Engineering Dept. and 4 years in the Geological Dept. 1904-05, Engineer for United Copper Co. 1905-09, Mining on own account.

Present position: Supt. Eclipse Mining Co., Marion, Ky.

**Perry Brace Wickham**, Alameda, Josephine Co., Oregon.

Proposed by L. Y. Keady, I. B. Hammond, James Lindsay.

Born, 1884, Fairmont, Minn. No college education, practical experience. 1900-07, Mine labor and study with small operation in personal interests. 1907-08, General foreman on development for Alameda Cons. Mines Co., Portland, Ore. 1908, Assayer on Mont. Metallurgical Works, Portland, Ore. 1909, Personal interests and study. 1910-11, Supt. Alameda Cons. Mines Co. 1912-13, Asst. Mgr. in charge of Mining and Smelting operations Alameda Cons. Mines Co.

Present position: Negotiating for lease and land on a mining and smelting proposition.

**Sidney Leo Wise, New York, N. Y.**

Proposed by J. F. Kemp, H. H. Wilkins, W. B. Devereux, Jr.

Born, 1888, Baltimore, Md. 1907, Grad. Columbia Grammar School. 1911, degree E. M., Columbia Univ., School of Mines. 1911-12, Asst. Engr. Suriana Mining & Smelting Co., Guerrero, Mex. 1912-13, Engineer for Mines Management Co., New York, at mine of Vermont Copper Co., So. Stafford, Vt.

Present position : Engineer with Mines Management Co.

**Louis M. Zach, Bonne Terre, Mo.**

Proposed by Thomas T. Read, C. J. Adami, O. M. Bilharz.

Born, 1887, New Haven, Conn. 1906-10, Columbia Univ., degree M. E. 1902-06, Boardman M. T. H. S., New Haven, Conn. ; Brooklyn M. T. H. S., Brooklyn, N. Y. ; De Witt Clinton H. S., New York City. 1893-1902, Eaton Grammar School, New Haven, Conn. 1910, Loen Mfg. Co., Cleveland, Ohio, draftsman. 1907, De La Vergne Mch. Co. 1910, Wells Bros. Co., Greenfield, Mass. ; efficiency engineer. 1911, Wickes Bros. Co., Saginaw, Mich., designer ; Sandusky Portland Cement Co., Syracuse, Ind., construction engr. 1912, Nicholson Tile Co., Port Hope, Ont., efficiency engineer ; Dominion Coal & Iron Co., Glace Bay, Nova Scotia, designer ; Dixie Portland Cement Co., Richard City, Tenn., construction engr.

Present position : Construction engineer with Doe Run Lead Co., Rivermines, Mo.

#### *Associate Members.*

**R. E. Murphy, Spokane, Wash.**

Proposed by Rush J. White, W. J. Hall, George W. Roddewig.

Born, 1880, Empire, Nev. Grad. Carson, Nev., High School, 1897.

Present position : 1902 to date, Salesman E. I. Du Pont de Nemours Powder Co.

**L. E. Warner, Larson, Idaho.**

Proposed by L. K. Armstrong, W. J. Hall, Francis A. Thomson, O. B. Hofstrand.

Born, 1866, Iowa.

Present position : Mill Foreman, Snow Storm Mining Co.

#### *Junior Members.*

**Charles L. Burdick, Boston, Mass.**

Proposed by Carle R. Hayward, H. O. Hofman, Edward E. Bugbee.

Born, 1892, Denver, Colo. 1911, Drake University, Des Moines, Ia. ; B. S. 1913, Mass. Inst. Tech., Boston ; B. S. Summer 1911-12, Asst. Chem. Testing Laboratory, Chicago & Northwestern Railway. Summer 1913, Research work, Mass. Inst. of Technology.

Present position : Grad. Student in Chemistry, Mass. Inst. of Technology.

**Robert Joseph Cole, Butte, Mont.**

Proposed by D. C. Bard, Theodore Simons, C. H. Bowman.

Born, 1890, Blue Earth, Minn. 1910-11, Student, College of Mines, Univ. of Washington. Summer 1910, Federal Mining and Smelting Co., Wardner, Idaho. Summer 1912, Bunker Hill & Sullivan Mining & Concentrating Co., Kellogg, Idaho. Summer 1913, West Colusa Mine, Amalgamated Copper Co., Butte, Mont.

Present position : Student, Montana State School of Mines. Senior Class.

**Joseph P. Lyden, 628 So. Wyoming St., Butte, Mont.**

Proposed by D. C. Bard, Theodore Simons, C. H. Bowman.

Born, 1891, Butte, Mont.

Present position : Senior, Montana State School of Mines.

**Brandon Patrick McMahon, Butte, Mont.**

Proposed by D. C. Bard, Theodore Simons, C. H. Bowman.

Born, 1892, Butte, Mont.

Present position : Student, Mont. School of Mines.



## CHANGES OF ADDRESS OF MEMBERS.

The following changes of address of members have been received at the Secretary's office during the month of November, 1913. This list, together with the lists published in *Bulletin* Nos. 76 to 83, April to November, 1913, and the foregoing list of new members, therefore, supplements the annual list of members corrected to Mar. 1, 1913, and brings it up to the date of Dec. 1, 1913.

|                                                                                  |                                                              |
|----------------------------------------------------------------------------------|--------------------------------------------------------------|
| ABBOTT, JAMES W.                                                                 | "St. Omer," 123 N. Grand Ave., Los Angeles, Cal.             |
| ADAMS, ARTHUR K.                                                                 | 700 Mundy Ave., El Paso, Texas.                              |
| ADAMS, WALTER C.                                                                 | 649 Roslyn Ave., Westmont, Que., Canada.                     |
| ANDERSON, MARTIN L.                                                              | Liberty Bell Mine, Telluride, Colo.                          |
| ALDERSON, VICTOR C.                                                              | 615 Ideal Bldg., Denver, Colo.                               |
| ALLEN, ROBERT.                                                                   | 8 Cliff Road, Leigh, Essex, England.                         |
| BACKUS, GEORGE S.                                                                | 617 Lieter St., Leadville, Colo.                             |
| BANKS, HARRY P.                                                                  | 5715 Julien St., Highland Park Sta., Los Angeles, Cal.       |
| BATCHELLER, JAMES H.                                                             | Mattapoisett, Mass.                                          |
| BAUMANN, ALBERT P.                                                               | 939 Boulevard, East Weehauken, N. J.                         |
| BERRY, JOHN F.                                                                   | 215 Walmer Road, Port Elizabeth, Cape Colony, So. Africa.    |
| BOLLES, MYBICK N.                                                                | 413 Wall St., Joplin, Mo.                                    |
| BRIGGS, W. A. J.                                                                 | Umukuri, Motueke, Nelson, New Zealand.                       |
| BRINSMAD, R. B.                                                                  | la Pensada Mexicana 3, Puebla, Pue., Mexico.                 |
| BROWNE, DAVID H.                                                                 | International Nickel Co., 48 Exchange Place, New York, N. Y. |
| BROWNING, WILLIAM C.                                                             | Magna Copper Co., Superior, Ariz.                            |
| COHEN, MAXWELL B.                                                                | Miami, Ariz.                                                 |
| COLE, DAVID, Engr., in charge, Concentration Dept., Arizona Copper Co., Ltd.,    | Morenci, Ariz.                                               |
| CREMER, FELIX                                                                    | Empire Steel & Iron Co., Wharton, N. J.                      |
| DARTON, N. H.                                                                    | U. S. Geological Survey, Washington, D. C.                   |
| DAVIS, JAMES C., 4th Vice-Prest, American Steel Foundries, 1163 McCormick Bldg., | Chicago, Ill.                                                |
| DEIKE, GEORGE H.                                                                 | Bureau of Mines, Pittsburg, Pa.                              |
| DRAPER, CARL H.                                                                  | 112 Bloomfield St., Dorchester, Mass.                        |
| ELDRED, BYRON E.                                                                 | Springfield, Maine.                                          |
| ESSELTYN JOHN N.                                                                 | Orogrande, New Mex.                                          |
| EVANS, MILTON R.                                                                 | 236 Gardner St., Plymouth, Pa.                               |
| FERGUSON, DONALD.                                                                | P. O. Box 644, Goldfield, Nev.                               |
| FLEMING, EDWARD P.                                                               | Fundicion de Guayacan, Coquimbo, Chile, So. America.         |
| FRANKE, EMIL A.                                                                  | 3852 Monticello, Irving Park Sta., Chicago, Ill.             |
| GIBB, ALLAN.                                                                     | 16 St. Helens Place, London, E. C., England.                 |
| GUNTHER, C. GODFREY.                                                             | Stratford, Conn.                                             |
| HARMS, ERNEST.                                                                   | 902 Upson Ave., El Paso, Texas.                              |
| HIBBS, JOSEPH G., Min. Engr., Geol. and Chem.                                    | Wawa, Pa.                                                    |
| HOAR, FREDERIC W.                                                                | P. O. Box 1951, Globe, Ariz.                                 |
| HOEFER, PROF. HANS.                                                              | Hintzerstrasse 10, 1, Vienna III, Austria.                   |
| HOFECKER, CHARLES A.                                                             | Allis-Chalmers Co., 5 Rue Saulnier, Paris, France.           |
| HUBBARD, HARRY J.                                                                | Marfa, Texas.                                                |
| HULICK, CHARLES E.                                                               | Thomas Iron Co., Hokendauqua, Pa.                            |
| IMHOFF, ALEXANDER.                                                               | P. O. Box 424, Tonopah, Nev.                                 |
| JONES, C. COLCOCK.                                                               | 605 I. N. Van Nuys Bldg., Los Angeles, Cal.                  |
| JONES, ZECHARIAH.                                                                | Idaho Continental Mines, Port Hill, Idaho.                   |
| JORGENSEN, FRANK F.                                                              | Gillespie, Ill.                                              |
| JULIHN, CARL E., Supt.                                                           | Sierra Nevada Mining Co., Virginia City, Nev.                |
| KEITH, FRANK A.                                                                  | 1219 Hollingsworth Bldg., Los Angeles, Cal.                  |
| KEMLER, W. H.                                                                    | P. O. Box 214, Johnson City, Tenn.                           |
| KEPNER, ROSS B.                                                                  | 1701 1/2 S. Union Ave., Los Angeles, Cal.                    |
| KIRKCALDY, NORMAN M.                                                             | P. O. Box 210, Sydney, N. S. W., Australia.                  |
| KLOPSTOCK, PAUL.                                                                 | 4 London Wall Bldg., London, E. C., England.                 |
| KLUTTZ, WARREN L.                                                                | Vice-Prest., Central Iron & Coal Co., Holt, Ala.             |
| LADD, DAVID H., Min. and Met. Engr.                                              | 110 Front St., Hancock, Mich.                                |
| LEACH, ROBERT H.                                                                 | 8 Brook St., Wesley, Mass.                                   |
| LINN, WILLIAM J., Min. Engr.                                                     | 2629 Michigan Ave., Chicago, Ill.                            |
| LUNN, ROBERT, JR.                                                                | Algona Club, Copper Cliff, Ont., Canada.                     |

|                                                                                      |                                                                  |
|--------------------------------------------------------------------------------------|------------------------------------------------------------------|
| McLURE, CHARLES D., Prest...                                                         | Granite-Bi-Metallic Cons. Mining Co., Philipsburg, Mont.         |
| McMASTER, A. T. C.....                                                               | 74 Victor Ave., Toronto, Ont., Canada.                           |
| McKEE, J. A.....                                                                     | 221 S. 4th St., Aurora, Ill.                                     |
| MACOMB, J. DE N., JR., Atchison, Topeka and Santa Fé Ry. System,                     |                                                                  |
|                                                                                      | 1033 Railway Exchange Bldg., Chicago, Ill.                       |
| MANAHAN, ROBERT F.....                                                               | 709 Mills Bldg., El Paso, Texas.                                 |
| MARSHALL, EMORY M.....                                                               | Yerington, Nev.                                                  |
| MENTZEL, CHARLES.....                                                                | Virginia Smelting Co., West Norfolk, Va.                         |
| MILLARD, WILLIAM J.....                                                              | Hartley Hall, Columbia University, New York.                     |
| MOORE, REDICK R.....                                                                 | Mines Management Co., 60 Broadway, New York, N. Y.               |
| MUSGRAVE, ROBERT.....                                                                | 1166 Deal St., Oak Bay, Victoria, B. C., Canada.                 |
| NISHIO, KEIJIRO.....                                                                 | Care Frau Wetzel, Fischerstr. 49, Freiberg III, Saxony, Germany. |
| OTTERSON, GEORGE W.....                                                              | Mansan, via Hazelton, B. C., Canada.                             |
| PACKARD, GEORGE A., Min. Engr. and Met.....                                          | 50 Congress St., Boston, Mass.                                   |
| PAINTER, ROBERT K.....                                                               | 131 W. 74th Street, New York, N. Y.                              |
| PESCHEL, WILLIAM M.....                                                              | 42 Allen St., Bradford, Mass.                                    |
| PHENIX, CHARLES E.....                                                               | Windsor House, Bellingham, Wash.                                 |
| PORTUGAL, J. H., Supt.....                                                           | Michigan-Utah Mining Co., Alta, Utah.                            |
| RHODES, WILLIAM B.....                                                               | Care E. E. Rhodes, Mendocino City, Cal.                          |
| RITER, LEVI E., JR.....                                                              | 306 Newhouse Bldg., Salt Lake City, Utah.                        |
| RODGERS, JOSEPH H.....                                                               | P. O. Box 825, Seattle, Wash.                                    |
| RODGERS, MYRON K.....                                                                | P. O. Box 825, Seattle, Wash.                                    |
| ROSE, GEORGE E.....                                                                  | 6758 Bennett Ave., Chicago, Ill.                                 |
| ROSS, EDWARD P., Supt.....                                                           | Colonial Iron Co., Riddlesburg, Pa.                              |
| RULE, J. ARTHUR.....                                                                 | 1121 Los Angeles St., El Paso, Texas.                            |
| SANBORN, JAMES F., Div. Engr., Board of Water Supply, 700 W. 181st St.,              |                                                                  |
|                                                                                      | New York, N. Y.                                                  |
| SANDERS, W. E.....                                                                   | Alkali Mines Co., Eureka, Nev.                                   |
| SAYRE, MORTIMER F.....                                                               | Center St., East Mauch Chunk, Pa.                                |
| SCHWARZ, T. E.....                                                                   | 67 Winthrop Road, Brookline, Mass.                               |
| SHAW, S. F.....                                                                      | Edificio La Mutua 200, Mexico City, Mexico.                      |
| SHOCKLEY, W. H.....                                                                  | 959 Waverly Street, Palo Alto, Cal.                              |
| SHOOK, JAMES W.....                                                                  | 3206 Cliff Road, Birmingham, Ala.                                |
| SLUSHER, DALE.....                                                                   | Pendleton, Ore.                                                  |
| SMITH, JAMES G.....                                                                  | Care Wyman & Gordon Co., Worcester, Mass.                        |
| SQUIRES, HOWARD W.....                                                               | 2722 W. 9th St., Los Angeles, Cal.                               |
| STAYER, WILLIAM H.....                                                               | 1626 Wood Ave., Colorado Springs, Colo.                          |
| SULLIGER, ROY A.....                                                                 | 1400 Hibernian Bldg., Los Angeles, Cal.                          |
| THOMAS, MARION L., Min. Engr.....                                                    | Room 1418, 71 Broadway, New York, N. Y.                          |
| THOMAS, DAVID R.....                                                                 | Care W. R. Cox, 165 Broadway, New York, N. Y.                    |
| THROCKMORTON, H. W.....                                                              | Kohl Building, San Francisco, Cal.                               |
| TORBERT, JAMES B.....                                                                | 426 James Bldg., Chattanooga, Tenn.                              |
| TREAT, LLOYD B.....                                                                  | Ingersoll-Rand Co., 109 E. Broadway, Butte, Mont.                |
| UNDERWOOD, ARTHUR J.....                                                             | 959 Boston Court, Pasadena, Cal.                                 |
| VAN ARSDALE, GEORGE D., Copper Queen Cons. Mining Co., 99 John St., New York, N. Y.  |                                                                  |
| VAN ZWALUWENBURG, A.....                                                             | la Madrid 15, Mexico City, Mexico.                               |
| WAINSWRIGHT, WILFRID B.....                                                          | Instructed to hold all mail.                                     |
| WARD, HARRY J.....                                                                   | 2731 Budlong Ave., Los Angeles, Cal.                             |
| WETHEY, A. H.....                                                                    | 37 Madison Ave., New York, N. Y.                                 |
| WILCOX, RALPH.....                                                                   | 115 Lydia St., Jackson, Mich.                                    |
| WOLF, HARRY J., Prof. of Mining, Colo. School of Mines, P. O. Box 666, Golden, Colo. |                                                                  |

## ADDRESSES OF MEMBERS AND ASSOCIATES WANTED.

| Name.                             | Last Address of Record, from which Mail has been Returned. |
|-----------------------------------|------------------------------------------------------------|
| Bacorn, Frederick W., . . . . .   | West Austin, Mich.                                         |
| Bentley, Thomas H., . . . . .     | Blake-McFall Bldg., Portland, Ore.                         |
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| 1884              | *Earle, Frank C., . . . . .     | —, 1913.           |
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DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at the New York meeting, February, 1914, when an abstract of the paper will be read. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y., for presentation by the Secretary or other representative of its author. Unless special arrangement is made, the discussion of this paper will close Apr. 1, 1914. Any discussion offered thereafter should preferably be in the form of a new paper.

## Mining and Mining Methods in the Southeast Missouri Disseminated-Lead District.

BY H. A. GUESS, FLAT RIVER, MO.

(New York Meeting, February, 1914.)

### INTRODUCTION. HISTORY AND PRODUCTION STATEMENTS.

SOUTHEAST MISSOURI is the oldest of the large producing districts of the United States. The first recorded production from disseminated ores was in 1869, although for many years prior to that time lead had been mined from shallow pockets, and steady growth in production has been shown ever since, the greatest increases being during the past five years.

The production by years for each of the operating companies from 1869 to 1907, inclusive, is given in Table I. In Table II. is given the production by years from 1908 to 1912, inclusive, for the district as a whole, showing the tonnage of crude ore mined, yield in concentrates, average assay of concentrates; yield in metallic lead both per ton of crude ore and in total; also approximate value of the yearly production.

It is interesting to note that the production for the 5-yr. period 1908 to 1912, inclusive, is practically equal to the total previous production, viz., the 39-yr. period 1869 to 1907, the summary being as follows:

| Period.                   | Lead Production.   |              |
|---------------------------|--------------------|--------------|
|                           | Tons Concentrates. | Gross Value. |
| 1869-1907, inclusive..... | 1,202,606          | \$59,869,354 |
| 1908-1912, inclusive..... | 1,042,553          | 58,914,260   |

a TABLE I.—*Production of the Lead Mines of the Bonne Terre,*

Compiled from various sources.

| Year. | St. Joseph Lead Co. |              | Desloge Lead Co.                                                                      |             | Desloge Consolidated Lead Co. |             | Flat River Lead Co.                            |          | St. Louis Smelting & Refining Co. |               | Doe Run Lead Co.   |              |
|-------|---------------------|--------------|---------------------------------------------------------------------------------------|-------------|-------------------------------|-------------|------------------------------------------------|----------|-----------------------------------|---------------|--------------------|--------------|
|       | Tons Concentrates.  | Value.       | Tons Concentrates.                                                                    | Value.      | Tons Concentrates.            | Value.      | Tons Concentrates.                             | Value.   | Tons Concentrates.                | Value.        | Tons Concentrates. | Value.       |
| 1869  | 161                 | \$36,540     |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1870  | 323                 | 40,052       |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1871  | 859                 | 95,968       |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1872  | 1,080               | 116,600      |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1873  | 1,080               | 118,000      |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1874  | 1,295               | 141,725      |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1875  | 1,963               | 210,432      |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1876  | 2,436               | 257,242      |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1877  | 2,051               | 169,002      | 928                                                                                   | \$76,467    |                               |             |                                                |          |                                   |               |                    |              |
| 1878  | 2,819               | 153,354      | 1,843                                                                                 | 100,359     |                               |             |                                                |          |                                   |               |                    |              |
| 1879  | 3,565               | 228,160      | 2,332                                                                                 | 149,248     |                               |             |                                                |          |                                   |               |                    |              |
| 1880  | 4,254               | 323,304      | 3,531                                                                                 | 268,356     |                               |             |                                                |          |                                   |               |                    |              |
| 1881  | 5,317               | 348,795      | 4,646                                                                                 | 314,778     |                               |             |                                                |          |                                   |               |                    |              |
| 1882  | 7,304               | 556,028      | 5,903                                                                                 | 443,906     |                               |             |                                                |          |                                   |               |                    |              |
| 1883  | 5,952               | 380,928      | 6,770                                                                                 | 509,004     |                               |             |                                                |          |                                   |               |                    |              |
| 1884  | 6,804               | 381,034      | 7,530                                                                                 | 421,680     |                               |             |                                                |          |                                   |               |                    |              |
| 1885  | 9,769               | 593,955      | 5,458                                                                                 | 331,846     |                               |             |                                                |          |                                   |               |                    |              |
| 1886  | 7,372               | 530,784      | 4,542                                                                                 | 327,004     |                               |             |                                                |          |                                   |               |                    |              |
| 1887  | 7,387               | 508,226      |                                                                                       |             |                               |             |                                                |          |                                   |               |                    |              |
| 1888  | 13,027              | 1,042,160    | The above mines were at Bonne Terre and in 1887 were purchased by St. Joseph Lead Co. |             |                               |             |                                                |          |                                   |               | 2,900              | \$22,000     |
| 1889  | 13,600              | 783,360      |                                                                                       |             |                               |             |                                                |          |                                   |               | 5,243.5            | 302,025      |
| 1890  | 13,851              | 952,000      |                                                                                       |             |                               |             |                                                |          |                                   |               | 5,516.4            | 280,000      |
| 1891  | 14,114              | 1,094,381    |                                                                                       |             |                               |             |                                                |          |                                   |               | 4,219              | 217,600      |
| 1892  | 13,474              | 896,098      |                                                                                       |             |                               |             |                                                |          |                                   |               | 3,348              | 124,700      |
| 1893  | 14,421              | 587,012      |                                                                                       |             |                               |             |                                                |          |                                   |               | 3,593.3            | 150,000      |
| 1894  | 18,069              | 763,279      |                                                                                       |             | 2,250                         | \$67,500    | 750                                            | \$22,500 |                                   |               | 4,509.3            | 190,000      |
| 1895  | 20,411.5            | 563,910      |                                                                                       |             | 4,200                         | 126,000     | Purchased by St. Louis Smelting & Refining Co. |          |                                   |               | 5,700              | 201,500      |
| 1896  | 21,908.5            | 659,451      |                                                                                       |             | 4,650                         | 129,782     |                                                |          |                                   |               | 10,342             | 311,294      |
| 1897  | 23,067              | 563,867      |                                                                                       |             | 5,200                         | 156,600     |                                                |          |                                   |               | 12,632             | 343,595      |
| 1898  | 20,342.5            | 798,454      |                                                                                       |             | 9,327                         | 366,084     |                                                |          |                                   |               | 12,400             | 487,063      |
| 1899  | 20,024.5            | 844,033      |                                                                                       |             | 10,044                        | 490,000     |                                                |          |                                   |               | 12,230             | 516,139      |
| 1900  | 18,174              | 823,282      |                                                                                       |             | 14,929                        | 477,371     |                                                |          | 3,064                             | \$122,223     | 19,075             | 906,382      |
| 1901  | 23,417              | 943,722      |                                                                                       |             | 7,497                         | 300,000     |                                                |          | 10,954                            | 448,521.5     | 16,532             | 804,961      |
| 1902  | 26,783              | 918,668      |                                                                                       |             | 9,950                         | 417,900     |                                                |          | 17,584                            | 664,123       | 17,080             | 810,850      |
| 1903  | 28,481              | 1,381,328    |                                                                                       |             | 9,449                         | 400,000     |                                                |          | 16,701                            | 704,782       | 19,420             | 946,548      |
| 1904  | 28,417              | 1,059,158    |                                                                                       |             | 12,742                        | 555,359     |                                                |          | 15,511                            | 696,002       | 19,100             | 933,539      |
| 1905  | 30,588              | 1,529,435    |                                                                                       |             | 13,488                        | 661,864     |                                                |          | 17,528                            | 876,404       | 19,300             | 1,001,476    |
| 1906  | 43,907              | 2,853,966    |                                                                                       |             | 11,641                        | 773,320     |                                                |          | 18,503                            | 1,066,242.6   | 20,082             | 1,313,051    |
| 1907  | 83,000              | 2,103,837    |                                                                                       |             | 10,051                        | 633,236     |                                                |          | 16,391                            | 1,040,845.1   | 19,670             | 1,284,875    |
| Total | 510,988             | \$26,357,453 | 43,483                                                                                | \$2,942,648 | 125,418                       | \$5,556,966 | 750                                            | \$22,500 | 116,186                           | \$5,641,143.2 | 232,852.6          | \$11,362,282 |

Total tons concentrates.....1,202,606.9

Total value.....\$59,869,354

a Missouri Bureau of Geology and Mines, vol. ix, part I.

Since 1905 and up until the close of 1912, the total production of the district has been made by five companies as follows:

| Name of Company.                       | Approximate.<br>Mill Capacity in<br>Tons per 24 Hours. | Approximate.<br>Acreage of Land<br>Owned. |
|----------------------------------------|--------------------------------------------------------|-------------------------------------------|
| Federal Lead Co.....                   | 4,500                                                  | 14,000                                    |
| St. Joseph Lead Co. <sup>b</sup> ..... | 3,200                                                  | 19,000                                    |
| Doe Run Lead Co. <sup>b</sup> .....    | 3,000                                                  | 7,094                                     |
| St. Louis Smelting & Refining Co.....  | 2,500                                                  | 1,300                                     |
| Desloge Consolidated Lead Co.....      | 1,800                                                  | 4,400                                     |

<sup>b</sup> At the close of 1913 these two companies were consolidated as one company—the St. Joseph Lead Co.

<sup>c</sup> By October, 1913, the Doe Run Lead Co.'s mill will be increased to 4,000 tons per 24 hr.



Beginning with 1913, production has been started in a small way by a new company in the district, the St. Francois Lead Co., which in 1910 purchased a well situated tract of 357 acres. This ore for the present is being shipped to the mill of the St. Louis Smelting Refining Co.

#### PHYSIOGRAPHY AND GEOLOGY.

"As a whole the district is rough and hilly, although the only areas that might be called mountainous are in the Southeastern and Southwestern parts in all which occur the Northern spurs of the granite and rhyolite hills and ridges which have been called the St. Francois Mountains. The remaining portion of the area consists of hills and valleys with narrow table land areas and alluvial plains.

"The lowest elevation in the district is 610 feet, along Big River and the highest 1530 feet at the summit of Middle Mountain."

The accompanying map, Fig. 1, which represents a portion of the U. S. Geological Survey sheets, Bonne Terre and Farmington quadrangles, in 20-ft. contours, shows clearly the surface features of the district, and on this map is drawn a circle of 5-mile radius within which all the disseminated-lead production of the district has been made, other than a few hundred tons from Irondale. Plate I. is a map of the same territory, showing the underground workings.

The Cambrian formation, within the confines of the producing disseminated-lead district, is made up of six members, as follows:<sup>1</sup>

| Name.           | Thickness, Etc.                                                     | Character.                                                                              |
|-----------------|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Potosi .....    | Occurs over only a small portion.<br>Normal thickness about 300 ft. | Massive beds of dolomite frequently with cherty nodules alternating with beds of chert. |
| Doe Run.....    | Normal thickness about 60 ft.                                       | Shaly dolomite.                                                                         |
| Derby.....      | Normal thickness about 40 ft.                                       | Massive dolomite.                                                                       |
| Davis.....      | Normal thickness about 170 ft.                                      | Shale and limestone conglomerate.                                                       |
| Bonneterre..... | Normal thickness about 343 ft.                                      | Dolomite chloritic and shaly near bottom.                                               |
| La Motte.....   | Normal thickness about 200 ft.                                      | White sandstone.                                                                        |

In general the disseminated-ore horizon occurs in the lower part of the Bonneterre formation, the main bed being usually within less than 50 ft. of the underlying sandstone, with occasional upper layers of ore ranging as far as 300 ft. above the sandstone. The sandstone itself near the top sometimes contains disseminated galena in sufficient amount to permit mining with the limestone, but this ore from the sandstone is relatively unimportant, amounting as it does to less than 1 per cent. of the total.

<sup>1</sup> *Missouri Bureau of Geology and Mines, vol. ix., Part I.*



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Art 2.

Practically all production is within the circle of 5-mile rad

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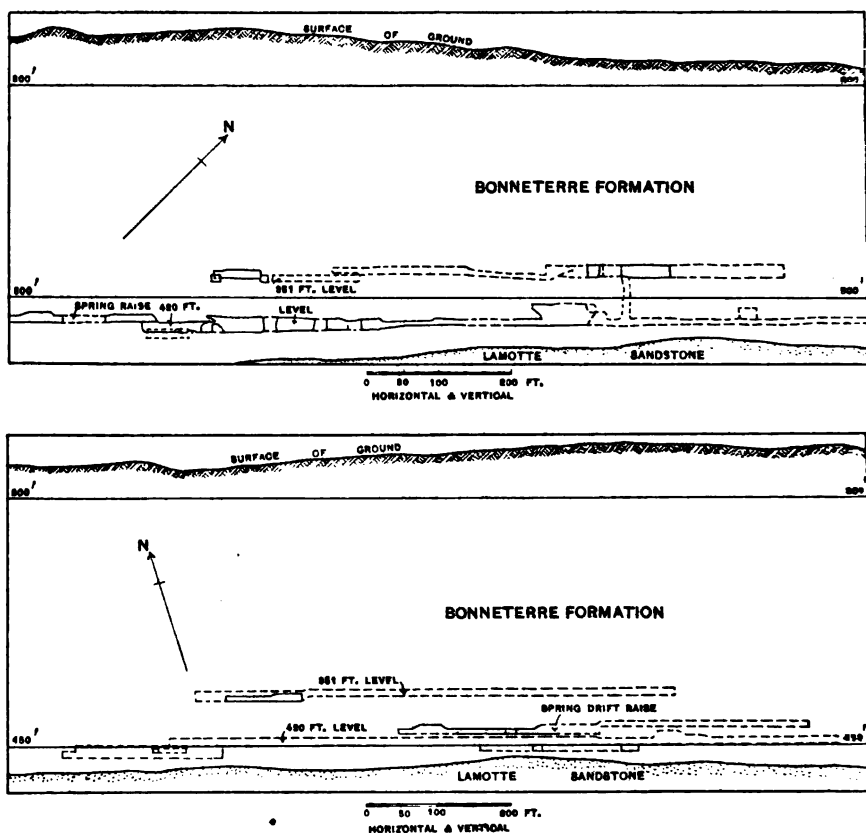
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The accompanying sections, Fig. 2, represent typical occurrences of the disseminated ore in the district where two or more levels are present.

### PROSPECTING.

As no outcrops of disseminated ore occur in the district, prospecting, both in the search for new orebodies and for the extension of known ore, is done entirely by drilling, and the formation, other



Missouri Bureau of Geology and Mines, Vol. ix., Ser. 2, Plate LIII.

FIG. 2.—CROSS-SECTIONS SHOWING POSITION OF OREBODIES WORKED IN FEDERAL MINE No. 1, WITH RESPECT TO THE SURFACE AND THE UNDERLYING LA MOTTE SANDSTONE.

than for a little Potosi here and there, is free of flint, so that diamond drilling is used exclusively after reaching solid rock, churn drills being used only for setting the sleeve pipe where the overlying soil or gravel is fairly deep. The district has received great assistance from the Missouri State Bureau of Geology and Mines, by its detailed study of the ore deposits and mapping of the area within



which ore may be expected to occur, but while this is very valuable in a broad way, the fact remains that in extending the limits of known orebodies the only way to do is to feel along with the diamond drill until the full limits of the body are defined. For this work close spacing of holes is used, usually 200 ft., sometimes as close as 100 ft.

For general prospecting in the search for new orebodies the holes are usually spaced 400 or 600 ft. or even further, either in checker-board fashion or in lines transverse with the supposed strike of the ore run.- Then when ore is cut, detailed drilling is begun with spacing of 200 ft. or less. All companies do not follow the same practice in this regard, however.

In drilling, the usual practice is to run with solid bit until within 50 ft. or so of the expected ore horizon and then core until the hole bottoms in La Motte sandstone or—in certain portions of the district—in porphyry or granite. A typical log of a diamond-drill hole where some Davis shale overlies the Bonnetterre lime, as taken from Federal Lead Co.'s record, is shown in the accompanying table.

*Typical Log of Diamond-Drill Hole.*

Number 2561

|          |              |                                                            |                       |
|----------|--------------|------------------------------------------------------------|-----------------------|
| Location | Tract No. 7. |                                                            |                       |
|          | N. 678.84.   | Sleeve 839.81.                                             | Date 5/19-5/31. 1918. |
|          | E. 1419.26.  | Bonne Terre Dolomite 776.81.<br>La Motte Sandstone 389.81. | Description by _____  |

| Core<br>Saved. | Depth. | Thick-<br>ness. | Description.                                         | Eleva-<br>tion<br>A. T. | Thick-<br>ness of<br>Ore. | Estimated<br>Lead Per Cent. | Accept-<br>ed Per<br>Cent. |
|----------------|--------|-----------------|------------------------------------------------------|-------------------------|---------------------------|-----------------------------|----------------------------|
|                | 8      |                 | Sleeve.....                                          |                         |                           |                             |                            |
|                | 63     |                 | Shale.....                                           | 776.81                  |                           |                             |                            |
|                | 340    |                 | Light lime.....                                      |                         |                           |                             |                            |
|                | 360    |                 | Gray lime.....                                       |                         |                           |                             |                            |
|                |        |                 | Began Coring.                                        |                         |                           |                             |                            |
| 1 ft. 0 in.    | 351    |                 | Dark gray lime, traces lead.....                     | 488.81                  | 1.0                       | traces                      |                            |
|                | 365    |                 | Dark gray lime, lead at 354-356-358-361-364.....     |                         |                           |                             |                            |
| 9 ft. 5 in.    | 375    |                 | Gray lime, traces lead.....                          | 464.81                  | 10.0                      | traces                      |                            |
| 2 ft. 0 in.    | 377    |                 | Gray lime, traces lead.....                          | 462.81                  | 2.0                       | traces                      |                            |
| 6 ft. 6 in.    | 384    |                 | Siliceous shale; gray lime; traces lead sulphur..... | 455.81                  | 7.0                       | traces                      |                            |
| 3 ft. 6 in.    | 387.5  |                 | Siliceous shaly gray lime.....                       | 452.31                  | 3.5                       | 2.0                         | 3.3                        |
| 10 ft. 3 in.   | 398    |                 | Gray shaly lime.....                                 | 441.81                  | 10.5                      | 8.0                         |                            |
| 1 ft. 11 in.   | 400    |                 | Gray shaly lime.....                                 | 439.81                  | 2.0                       | 7.0                         |                            |
| 9 ft. 8 in.    | 410    |                 | Siliceous chloritic gray lime.....                   | 429.81                  | 10.0                      | 1.0                         |                            |
| 4 ft. 0 in.    | 414    |                 | Siliceous shaly gray lime; traces lead.....          | 425.81                  | 4.0                       | traces                      |                            |
|                | 420    |                 | Gray shaly lime.....                                 |                         |                           |                             |                            |
| 1 ft. 6 in.    | 421.5  |                 | Chloritic gray shaly lime; traces lead.....          | 418.31                  | 1.5                       | traces                      |                            |
|                | 423    |                 | Gray shaly lime.....                                 |                         |                           |                             |                            |
| 3 ft. 11 in.   | 428    |                 | Siliceous sandy gray lime.....                       | 407.81                  | 9.0                       |                             |                            |
| 1 ft. 11 in.   | 435    |                 | Siliceous sandy gray lime; traces lead.....          | 404.81                  | 8.0                       | traces                      |                            |
| 7 ft. 0 in.    | 442    |                 | Siliceous sandy gray lime; traces lead.....          | 397.8                   | 7.0                       | traces                      |                            |
| 3 ft. 7 in.    | 446    |                 | Siliceous shaly gray lime; traces lead.....          | 393.81                  | 4.0                       | traces                      |                            |
|                | 450    |                 | Gray sandy lime; traces lead at 449.....             | 389.81                  |                           |                             |                            |
|                | 460    |                 | Clear white sand.....                                | 379.81                  |                           |                             |                            |
|                |        |                 | Bottomed at 460.0.                                   |                         |                           |                             |                            |
|                |        |                 | Water returned.                                      |                         |                           |                             |                            |
|                |        |                 | Pay                                                  |                         |                           |                             |                            |

The mineral run of the drill core is not as a rule assayed, except from time to time as a check on the estimations, but instead of this the mineral run is filed in a core tray, suitably labeled, its metallic lead contents carefully estimated, and the tray filed in the corehouse for future reference. Where a dozen or more drills are being operated by a company, a trained estimator is kept steadily engaged upon this work.

The costs per foot for diamond drilling in the district depend upon the distance for haulage of fuel, facilities for water, the contour of

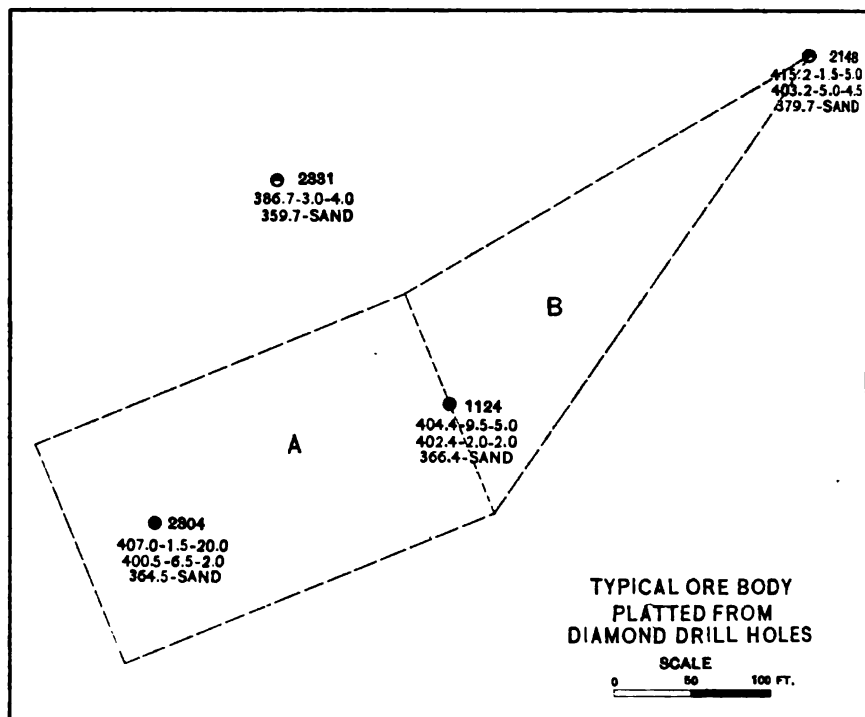


FIG. 3.—MAP OF OREBODY PLOTTED FROM DIAMOND-DRILL HOLES.

the ground, the rock formation, the depth of hole, the proportion of solid-bit to core-bit work, and the amount of time and care spent upon the collecting, estimating and storing of the cores, and it varies accordingly from 60 c. to \$1 per foot with an average of say 75 c., made up about as follows:

|                               |        |
|-------------------------------|--------|
| Labor.....                    | \$0.25 |
| Carbons.....                  | 0.25   |
| Fuel, etc., and haulage ..... | 0.10   |
| Repairs and renewals.....     | 0.15   |
|                               | <hr/>  |
|                               | \$0.75 |

In point of footage per 10-hr. shift solid-bit work will average say 60 ft. and core bit 30 ft. Approximately 25 per cent. of the total footage is cored. Careful attention is, in general, given by the companies to plotting upon their maps the drill holes and their records of ore, and calculating therefrom the probable orebody in terms of tonnage, thickness and grade. Experience has shown that in general the estimates thus made are fully borne out when it comes to actual working underground, so that ore reserves thus calculated can be safely relied upon.

The subjoined portion of a 50-ft. scale map, Fig. 3, shows a typical area in which drilling has yielded a number of pay holes and the orebody shown has been plotted as a result.

This will serve to illustrate the method of calculating tonnage, thickness and grade, as used by one of the larger companies of the district—the Federal Lead Co.—as follows:

|                                   |        |
|-----------------------------------|--------|
| Portion A, area: 250 by 150 ft. = | 37,500 |
| Portion B, area: 352 by 66 ft. =  | 23,232 |
| Total area.....                   | 60,732 |

In calculating thickness and grade of the orebody, each hole is first considered separately and then all are combined to obtain an average, thus:

| Hole.                    | Elevation. | Thickness.<br>Ft. | Pb.<br>Per Cent. | Ft-Per Cent. |
|--------------------------|------------|-------------------|------------------|--------------|
| 2,304                    | 407.0      | 1.5               | 20.0             | 30.0         |
| .....                    | 400.5      | 6.5               | 2.0              | 13.0         |
| Totals and averages..... |            | 8.0               | 5.4              | 43.0         |
| 1,124                    | 404.4      | 9.5               | 5.0              | 47.5         |
| .....                    | 402.4      | 2.0               | 2.0              | 4.0          |
| Total and averages.....  |            | 11.5              | 4.5              | 51.5         |
| 2,148                    | 403.2      | 5.0               | 4.5              | 22.5         |
| Total and average.....   |            | 5.0               | 4.5              | 22.5         |

To find the average thickness and grade of the entire orebody, all holes within the limits of the body are considered. In this particular case the body was cornered at 2148 as the ore in this hole is scarcely a pay run.

| Hole                             | Elevation.  | Average<br>Thickness.<br>Ft. | Average<br>Per Cent. Pb. | Ft-Per Cent. |
|----------------------------------|-------------|------------------------------|--------------------------|--------------|
| 2,304                            | 400.5-408.5 | 8.0                          | 5.4                      | 43.2         |
| 1,124                            | 402.4-413.9 | 11.5                         | 4.5                      | 51.8         |
| 2,148                            | 403.2-408.2 | 5.0                          | 4.5                      | 22.5         |
| Totals and averages.....         |             | 24.5                         | 4.8                      | 117.5        |
| Average thickness and grade..... |             | 8.2                          | 4.8                      |              |

Calculations for tonnage are given below, using 11 cu. ft. per ton and figuring only 50 per cent. of the volume as ore, the rest being considered poor ground and pillars.

| Thickness.<br>Ft. | Grade of<br>Ore<br>Per Cent. | Area of<br>Body.<br>Sq. Ft. | Volume of<br>Body.<br>Cu. Ft. | Volume of Ore.<br>Cu Ft. = 50 Per<br>Cent. of Vol. of<br>Body. | Tons Ore.<br>11 Cu. Ft.<br>to Ton. | Tons<br>Pb. | Elevation of<br>Body. |
|-------------------|------------------------------|-----------------------------|-------------------------------|----------------------------------------------------------------|------------------------------------|-------------|-----------------------|
| 8.2               | 4.8                          | 80,782                      | 496,002                       | 249,001                                                        | 22,637                             | 1,087       | 400.5-413.9           |

## MINING.

### *Location of Shafts and Hoisting.*

Shafts are preferably located centrally to the tributary orebodies, and should be at a point where the sandstone—which is the limiting lower horizon of the ore—is lowest, so that a skip pocket may be cut—if skips are used—and a pumping sump arranged at a level low enough to bring both ore and water to it on a down grade.

In earlier days the hoisting was by cages and cars, but the use of skips is becoming more general, the usual practice for this being double skips of 5 tons capacity with loading pocket of 100 tons or more and loading gates operated with compressed air. Pockets are usually lined with steel rails.

Of the 21 shafts now operating in the district, 17 use cages and cars, and four use skips; 12 use electric hoisting and the rest steam. Average rope speeds during hoisting are in the former case 800 to 1,000 ft. per minute for cages and 500 to 550 ft. per minute for skips, while with steam they are 960 to 1,200 ft. for cages and 500 to 800 ft. for skips.

### *Ore Breaking.*

Stopes are carried for the full height of the orebody and the broken ore shoveled from the flat bottom into cars. Where the ore is not thicker than 8 ft. the stope is carried by breast holes from drills mounted on columns. If top and bottom of the stope both present good bedding planes to break to, the stope can be carried with two holes up to a 7 ft. height, otherwise three holes will be required. Where three holes are used the top and bottom holes are in the same vertical plane and the middle hole is set forward 6 in. nearer the face to be broken. The top hole looks up a little, the middle hole looks down just enough to hold water, and the bottom hole also looks down a little.

All the holes are carried approximately parallel with the face. In starting off such a stope, say as in turning around a pillar, three short—4 to 6 ft. length—holes are drilled as a cut to start the stope. The average length of regular breast hole is 7 to 7.5 ft. For stopes

too high to break from a column, the upper part is carried forward by breast holes precisely as in regular column-high ground, and the lower portion or stope is broken by vertical holes, the bottom being trimmed by lifters. Where the portion below the breast is only say 10 ft. thick it will be broken by one series of vertical holes of 7 to 7.5 ft. depth and the remaining 8-ft. layer taken up cleanly by flat holes or lifters. These flat holes ordinarily look down only sufficient to hold water and are drilled usually to 10 ft. length.

This same procedure is followed up to a maximum thickness of say 14 ft. for this portion below the breast, unless the floor is good to break to, in which case very few lifters are used and the 14 ft. is broken in two successive layers, by vertical holes. This same method of carrying forward the breast and then breaking the lower or stope portion by breaking in layers with vertical holes is used up to the extreme heights of stopes, which sometimes run to 70 ft.

In regard to spacing for holes and the burden to be carried, where column-high ground is being carried by two breast holes, the burden is usually 3 ft.; where three holes are used the two back holes carry 4 ft. of burden and the middle 3.5 ft. For stope holes except close to pillars the spacing is approximately 8-ft. centers and the burden 5 ft.

In loading these holes, for breast work, the two rear holes usually take 12 0.5-lb. sticks of 35 or 40 per cent.,  $1\frac{1}{8}$ -in. powder, either nitro-glycerine or gelatine. The middle hole is loaded with about 14 sticks or 7 lb. and is fired first. In stope holes, where, as is often the case, three holes are drilled in a row between pillars, the two end holes are each charged with about 12 sticks of powder and the middle with 18, and the middle hole fired first. The charge for the lifters varies but in general is much lighter per foot, as the burden is less both in point of measurement and because of its shattered condition.

In driving the breast, care is exercised in pointing the upper holes, to avoid breaking into and burning the roof or back. Loose or drummy portions of the back are taken down by flat gads or moils, using black powder whenever it is necessary to shoot any of these portions.

In point of danger from roof falls, the experience is that tight limestone is the safest and most dependable roof, while shaly backs are the most dangerous, frequently coming down without warning, especially if they show water seepage. Such roofs require pillars at frequent spacing. Also it is often necessary to take down the roof in a manner so as to arch it between pillars. For average ground, however, pillars are spaced about 30 ft. between circumferences and are of 18 ft. average diameter, representing approximately 15 per cent. by volume of the total ground mined.

In turning pillars the holes are placed so as to shoot away from the pillar and avoid danger of shattering.

Where more than one level is worked, care is used to insure that wherever levels, which are close together, overlap, their pillars will

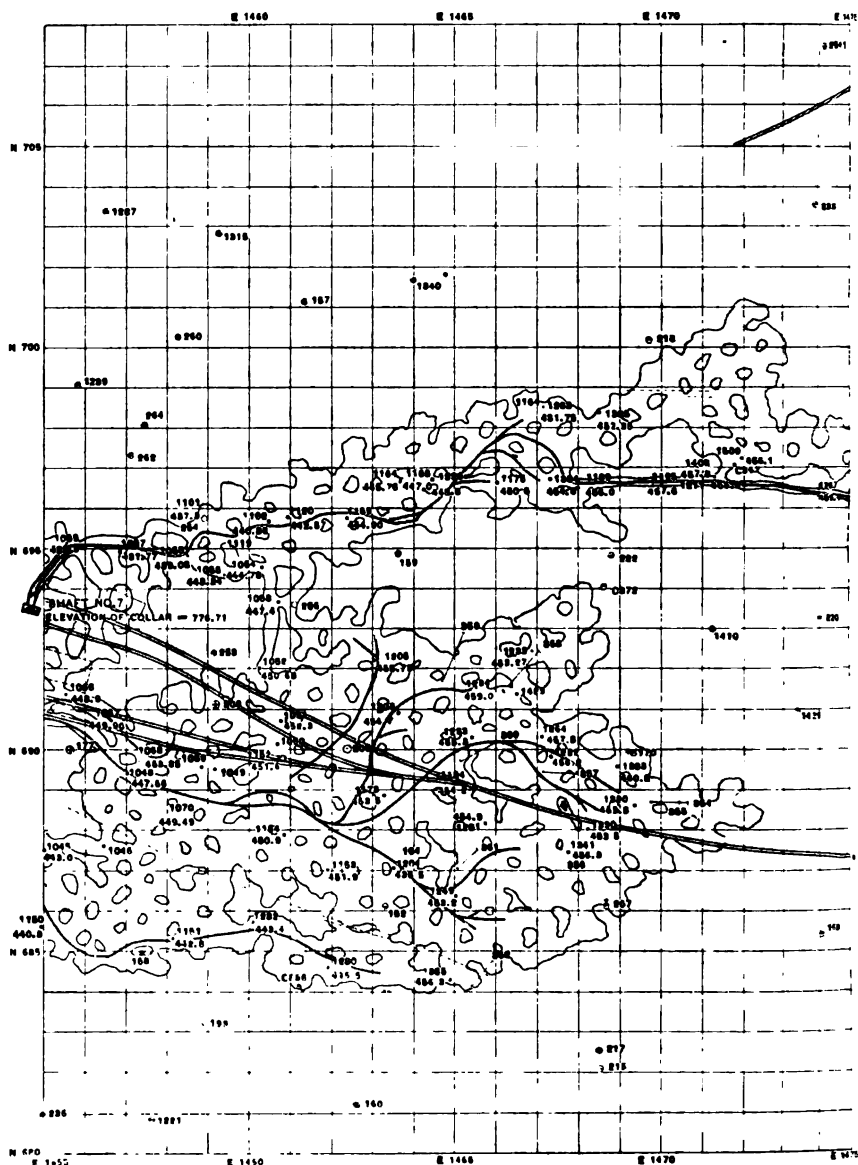


FIG. 4.—MAP OF A PORTION OF A TYPICAL ONE-LEVEL MINE.

be properly centered, the upper over the lower. The map, Fig. 4, represents a portion of a typical one-level mine in which the stopes vary from 7 to 40 ft. in height.

*Powder.*

The bulk of the powder used is 40 per cent. gelatine or nitroglycerine with some 35 per cent. gelatine; No. 6 caps and rubber- or gutta percha-covered fuse are used.

*Drills.*

Less than 5 per cent. of the drills of the district are now run with two men, and it is probable that within another year nothing but one-man drills will be in use. The type first adopted by those companies who changed from two-man to one-man drills was the Sullivan U.S. 2.25-in., and there are still more of those drills than of any other in use in the district. Within the past year, however, faster cutting drills than even the 2.25-in. Sullivan have been sought, and as a result one company has adopted water Leyners throughout, while two other companies are using the Ingersoll C-110 2.75-in. butterfly-valve drill for a large part of their work. Attention has also been given of late to the large amount of time consumed particularly in tripod work in setting up, even with the one-man drill, and several of the companies are therefore beginning now to use hammer drills of the self-rotating type for down holes and even for lifters. These hammer drills for holes of not over 8 ft. depth will drill fully as fast as piston drills and no time is consumed in setting up, while the air consumption is only about one-half that of a 2.75-in piston drill.

Steel is 1-in. octagon, solid, except for the Leyners, while for the hammer drills  $\frac{7}{8}$ -in. hollow steel is used. The sets are of 2 ft. range from 2 to 12 ft. for piston drills and 2 to 10 ft. for hammer drills. Machine sharpening is quite general throughout the district, using either the "Z" bit or the + bit, and for the hammers a 6-star bit.

Up until 1908 the ore was either broken by day's pay or else by contract at so much per linear foot of hole drilled. This latter system did not prove satisfactory, however, as great care was necessary to insure accurate measurement of the holes, and it was also found that the proper tonnage per foot of hole was not being obtained, the tendency, even with close supervision, being to locate holes more with reference to ease in setting up than to tonnage they would break.

In the fall of 1908 the system was introduced by the Federal Lead Co. of letting small contracts of two or more stopes to suitable men at so much per ton for breaking. This system compared to day's pay has some drawbacks in that it is not as flexible in the way of shifting the work from place to place without notice. Also it takes some care to keep proper records of the tonnage pulled for each contract,

but on the other hand it has built up an excellent group of machine men in the district, who, whether as contractors or as employees of these contractors, are, by skill in placing holes and by close attention to their work, able to earn on an average say 15 to 20 per cent. more than the prevailing company wage of \$2.75 for underground drilling, and to do this at a contract cost per ton that is fully as low as could be obtained by company day's pay operations at the prevailing wage.

That the system has upon the whole proved satisfactory both to the companies and the machine men is seen from the fact that over 80 per cent. of the tonnage of the district is now broken by per-ton contract, at a cost for labor of about 11 c. per ton, and an average earning—figuring the shifts of labor into the amount paid—of close to \$3.25 per man per shift. A large item of labor expense in connection with ore breaking is that of roof miners to take down all loose rock and keep the backs safe. This is taken care of by day's pay. Adding this cost to the 11 c. makes a total of approximately 14 c. as total drilling labor cost per ton.

Consumption of air and of powder has also been lessened by the contract system, as more skill is used in placing holes and therefore more tonnage broken per linear foot of hole. Approximately 29 ft. of holes are drilled per shift per single machine and approximately 1 ton is broken per foot of hole.

Power costs, as compressed air for drilling, are approximately 5 c. per ton and explosives 8 c. Air is distributed to the drills at about 80 lb. pressure.

Stopes are wherever possible arranged so that if the ore bed has a little dip, the stope approaches it from the lower side and works uphill, so as to ease the ore haulage and keep the faces or headings free of water without the use of heading pumps, which, operating as they must, on compressed air, are expensive. Tracks are all 24-in. gauge and 25-lb. steel is the usual weight. Ties are of oak 4 by 6 in. by 4 ft. and are spaced 2-ft. centers.

#### *Development Work.*

Drifts are cut 7 ft. high by 8 ft. wide, and while the center-cut method of breaking is sometimes used it is chiefly for extra wide or 10-ft. drifts for double track, and in general the side-cut method is used. In this method, 12 holes are usually used. This will square 3.5 to 4 ft. These 12 holes are made up thus:

First.—Four holes in a vertical row for the cut with a depth of 4 to 6 ft., collared about 3 ft. from the side of the drift and looking so as to meet the side line at their bottoms.



Second.—Three holes in a vertical row, collared 18 in. behind the cut row. These look less sharply, so their bottoms are 80 in. from the side wall. These average 7 ft. in depth so as to gain ground in going across the drift.

Third.—Three holes in a vertical row close to the far wall of the drift and looking parallel therewith, having a depth of 8 to 10 ft. Then in front of these three holes and spaced between top and middle and between bottom and middle are two relief holes of same depth, but looking a little toward the cut side.

In case of hard-breaking ground 16 holes are sometimes necessary, made up in that case of four vertical rows of four holes each. The different vertical rows are fired in series from cut side to square-up side. This gives a beveled square-up or face to the drift and the next slice is taken by reversing and putting the cut holes on the opposite side.

Raises are nearly all put up on a 45° to 50° slope following the same breaking method as in drifts, usually taking 16 holes in the raise. These raises are put up 7 by 10 ft. and a manway is then partitioned off at one end by cutting hitches and putting in 8- by 8-in. stulls every 6 ft., lining this with 2-in. oak. The manway is provided with a ladder or preferably a stairway and the end is closed with entrance at the side, thus avoiding danger to the loaders below from rocks falling down the manway. The gate at the bottom of the chute is usually of sector type operated with crank arm over which is placed a 2.5-in. pipe for leverage.

### *Shoveling and Trimming.*

All ore in the district is shoveled off a flat bottom into cars, which are trammed to raises and dumped, if on an upper level, or to the shaft if upon the main level.

Up until the end of 1912 nothing but hand work had ever been used for shoveling, but in January of this year the Federal Lead Co. introduced mechanical loading in a trial way at one of its mines and since that time has been shoveling with this mechanical shoveler about 7,000 tons per month, working two shifts per day. This machine is the No. 4 Myers-Whaley shovel made in Knoxville, Tenn., and was first described at length in *Engineering News*, Sept. 5, 1912. In this machine there are two distinct operations for loading and conveying. The loading element has a forward shoveling or thrusting movement actuated by a rotating crank and as the crank moves further it lifts the shovel through the material until the shovelful slides down into the inner or rear shovel. As the crank continues to

rotate the rear shovel is forced backward and up the inclined cam way until finally at the end of the stroke the material is discharged upon the belt conveyor and thence to the car. The shoveling action is continuous and automatic.

The accompanying photographic view, Fig. 5, gives a general idea of the machine as at work. It is improbable that it will ever be found profitable to use this mechanical shovel except in stopes 20 ft. or more in height, as in the lower stopes the small size of the piles of broken rock would render necessary the frequent moving of the shovel. In high stopes, however, especially 40 ft. or higher, where the broken piles are large, the shovel is likely to find extended appli-



FIG. 5.—MYERS-WHALEY NO. 4 MECHANICAL SHOVEL AT WORK,  
FEDERAL LEAD CO.'S SHAFT NO. 11.

cation in this district, and although it is doubtful if it will on an average give a per ton shoveling cost any lower than hand shoveling, it will be especially useful in times of labor shortage or when an increase in production is desired.

The tonnage shoveled per man for hand shoveling depends upon the supply of rock and the condition of the floor; it averages for the district about 18 tons per man. Long-handled, round-pointed No. 2 shovels are used requiring about 130 shovelfuls to fill a 1-ton car or 15 lb. per shovel. The cost per ton for shoveling averages 13 c.

Ore cars of the district are in general 1-ton cars of rectangular shape with flat or round bottoms. They are dumped at the top land-

ing by tippie, being pushed by hand either into the tippie or, as in case of Desloge, by air- or steam-operated piston, with a suitable hook at the end of the piston to hold the car and return it to the cage. Self-dumping cages of the type frequently seen in coal fields are used at one or two shafts in the district.

The power-dumped cars are usually a little larger than those for hand tippie dump, being of 1.5 to 1.75 tons capacity. Cars of "A" dump model of 1.4 tons capacity are used at the Federal for dumping into pockets for skip hoisting.

Cages, where used, go to solid landing at bottom and rest upon chairs at top landing, the latter being pushed in and out by lever.

In the matter of car wheels and bolsters, the styles are not uniform throughout the district but the practice at the Federal may be taken as fairly typical. Two types are there used:

First.—Roller-bearing bolsters with cast-iron wheels sufficiently open at the spokes to permit spragging on down grades by inserting a 2-ft. length of 1.25-in. pipe. These run with little friction and in that respect are the most satisfactory. Further, once packed with cup grease they require no more attention for oiling for three months or more. For miscellaneous work, however, where the grades are frequently over 3 per cent. these cast-iron wheels are liable to break by spragging under loaded train, and for such ground the second type is used.

Second.—Cast-iron bolsters, which are bored out to fit 2-in. axles but are not babbitted, and manganese-steel wheels with axle put on by hydraulic pressure. The axle is held in place in these bolsters by a fork and the bolster has a sump or oil cellar from which oil flows to each axle, using Summer black oil.

Mules are in general used only in gathering cars from the headings, while for haulage to the shaft, particularly where the distance is great, power haulage is used. At the Federal and St. Louis Smelting & Refining Co. (National) electric haulage is used exclusively; 250-volt direct-current locomotives, mostly 6-ton size, are used, and are run either single or double header according to the train load. At the St. Joseph and Doe Run, Porter high-pressure air locomotives are used, varying in size from 4 to 9.5 tons weight. Some gasoline locomotives are also in commission. At Desloge gasoline locomotives are used exclusively for power haulage underground, the Desloge being the first to adopt gasoline haulage in the district.

Tramming costs, underground, for gathering with mules and haulage to shaft, average about 5 c. per ton exclusive of track work.

### *Lighting.*

Lighting underground at stations and along drifts is by electric incandescent lamps. For individual lights for the men "sunshine" is used exclusively. About three years ago an economy in the use of this material was introduced by the Federal company, which arranged with the manufacturers to mold this into briquettes of a size to last 8 hr., thus avoiding the waste incident to dealing this out in bulk. The size is usually one brick of 12 oz. for shovelers and machine men and 1.5 bricks to drivers, and hand miners who do more traveling.

### *Drainage.*

The amount of water pumped from the mines is greater in the spring, but the year's average for the district<sup>2</sup> is about 12,500 gal. per minute under an average friction and static head of 500 ft. The tendency for pumping as for other large power requirements is to centralize power generation and distribute power electrically, but progress in this respect has not gone as far in the case of mine pumping, so that at the present time the bulk of the water, that is to say approximately 8,000 gal. per minute, is still handled by steam pumps, while 8,000 gal. per minute is pumped by motor-driven centrifugals, usually five stage,<sup>3</sup> and 1,500 gal. per minute by motor-driven geared plunger pumps, triplex or quadruplex. Most of the steam pumps are duplex tandem-compound with jet condensers, with one or two fly-wheel pumps, the latter being naturally more efficient. On the whole, however, the steam pumping will not show an efficiency over 45 per cent. carried back to the boiler.

The centrifugal pumps will average about 55 per cent. efficiency, similarly considered, and the geared plunger pumps not over 75 per cent., so that the pumping for the district as a whole shows about 50 per cent. efficiency carried back to the boiler. This figures a power consumption operating continuously of approximately 3,200 h-p. or about 7 h-p-hr. per ton of ore on the 1912 production, making a drainage cost for the district of about 8 c. per ton including labor, supplies, and repairs.

### *Power.*

Considerable progress has been made during the past few years by the operating companies in the way of centralizing power generation.

The St. Joseph and Doe Run each have central power plants with

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<sup>2</sup> Compiled from information given by the managers of the different operating companies.

<sup>3</sup> By April, 1914, approximately 2,500 gal. per minute now pumped by steam will be handled by motor-driven geared quadruplex plunger pumps.

Loomis-Pettibone and Westinghouse gas producers, and double-acting twin-tandem Snow horizontal gas engines direct connected to 6,600-volt, three-phase, 50-cycle generators, and distribution is made at that voltage. In addition, the St. Joseph has steam turbines both high pressure and mixed pressure, and Corliss compound, condensing reciprocating engines.

The Federal has one central power plant using chain grate stokers and Curtis turbines, current being distributed at 2,200 volts, three phase, 60 cycles; also some auxiliary steam plants for pumping, air compressing, and hoisting.

The National central power plant uses underfeed stokers, reciprocating engines, direct-current generators, and distributes at 500 volts.

The Desloge uses chain stokers and reciprocating engines direct connected to the mill.

Coal comes from various points in Illinois, costing on mine run base 90 c. to \$1.10 f.o.b. mines with freight rates from 70 to 90 c. per ton.

Total power consumption<sup>4</sup> for the district averages about 10,000,000 h.p.-hr. per month, and figuring this in horsepower-hours per ton of ore mined and milled gives 30 hr., the distribution being about as follows:

|                                |      |
|--------------------------------|------|
| Air compressing.....           | 6.5  |
| Drainage.....                  | 7.0  |
| Underground haulage.....       | 0.8  |
| Hoisting.....                  | 1.2  |
| Crushing and milling.....      | 13.0 |
| Lighting.....                  | 1.0  |
| Heating and miscellaneous..... | 0.5  |
| Total .....                    | 30.0 |

In the matter of coarse crushing, the St. Joseph, Doe Run, and Desloge crush to about 4-in. size, with gyratories at each shaft, before hauling to mill, while at Federal and National all crushing both coarse and fine is done at the mill.

Surface transportation from shafts to mills is done by standard-gauge steam railroads. The Federal, Desloge, and National each have a railroad of their own for haulage service only, while the St. Joseph and Doe Run control a railroad of about 60 miles length which, in addition to ore service, does a general freight and passenger business.

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<sup>4</sup> Compiled from information given by the managers of the different operating companies.

*Acreage Mined.*

Approximately 540 acres of ground, excluding pillars, has been stoped since the commencement of mining in the district, of which about 285 acres was mined from 1869 to 1907, and about 255 acres from 1908 to 1912, inclusive. During the past few years the number of tons of crude ore per acre mined has averaged for the district about 75,000.<sup>5</sup>

*Mining Costs, Tons per Man, Etc.*

Costs per ton for crude ore mined and delivered to mill bins average about 85 c. for the district, exclusive of diamond drilling and other prospecting which is variable with the different companies and may range from 5 to 15 c. per ton.

Tons per man for all underground labor averages about 5.7, distributed about as follows:

| Classification.                          | Tons per Man. |
|------------------------------------------|---------------|
| Superintendent, foremen and bosses.....  | 195           |
| Stablemen.....                           | 650           |
| Mule drivers.....                        | 55            |
| Motormen.....                            | 500           |
| Gatemen and chute tenders.....           | 400           |
| Spraggers and car dumpers.....           | 400           |
| Blacksmiths and helpers.....             | 500           |
| Trackmen.....                            | 100           |
| Hand miners (for safety of roofs).....   | 90            |
| Blasters.....                            | 800           |
| Cagers and landers.....                  | 180           |
| Watchmen, car cleaners and yardmen.....  | 250           |
| Machine-drill men.....                   | 29            |
| Shovelers.....                           | 18            |
| Miscellaneous.....                       | 200           |
| Average for total underground labor..... | 5.7           |

The crude-ore output as tons per man for all employees of the five operating companies, for prospecting, mining, and milling was 2.96 for the year 1911;<sup>6</sup> for 1912 the State report will doubtless show a little higher, due largely to progress in the way of centralizing operations, particularly power generation, milling, and hoisting.

<sup>5</sup> Compiled from information given by the managers of the different operating companies.

<sup>6</sup> According to the *Twenty-fifth Annual Report of the Missouri Bureau of Mines*.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Feb. 1, 1914.

## Monolithic Magnetite Linings for Basic Copper Converters.\*

BY ARCHER E. WHEELER AND MILO W. KREJCI, GREAT FALLS, MONT.

(Butte Meeting, August, 1913.)

### *Introduction.*

THERE are two general methods in use for the production of metallic copper from matte which are worthy of consideration: (1) the Welsh blister process, and (2) the converter process.<sup>1</sup>

As practically all of the copper produced to-day is made in converters, we will give a brief outline of that process before proceeding with the special subject of this paper.

Matte may be roughly defined as a mixture of the sulphides of copper, iron, nickel, silver, etc.

In the converter process this is blown up to metallic copper in a modified type of Bessemer converter.

The conversion of matte consists mainly in, (1) the removal of sulphur in the form of  $\text{SO}_2$ , and (2) the slagging of the iron.

With this brief statement we come to the two subdivisions of the process of converting mattes:

Converting with acid linings.

Converting with basic linings.

### *Converting with Acid Linings.*

This is carried out by lining the converter with siliceous rock or ore, which performs two functions: It protects the iron shell of the converter from the molten charge, and it furnishes the silica for combining with the iron as it is oxidized from the matte, to form a ferrous silicate. It follows from the second of these functions that this siliceous lining must be replaced from time to time, and in practice it has been necessary to reline converters every 8 to 40 hr., this time varying in different plants and even with different linings in the same plant, the life of a lining depending upon the grade of the matte treated, and upon the composition, the thickness, the tamping, and the drying of the lining.

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\* U. S. Patent 1,068,470, process of forming furnace linings, issued July 29, 1913, to Archer E. Wheeler and Milo W. Krejci.

<sup>1</sup> Peters: *Practice of Copper Smelting*, p. 460 (1911).

The process was modified by the introduction of siliceous ore into the converter through the mouth, during its campaign, thus prolonging the life of the lining by furnishing some of the silica necessary to flux the iron. It never became possible in practice to prolong the life of the lining more than a few hours, due to the mechanical wear and wash of the heavy and hot charge.

It will thus be seen that the acid lining was expensive and cumbersome.

#### *Converting with Basic Linings.*

A few years ago basic linings of magnesite brick came into use. After the first demonstrations had shown the advantages their use spread rapidly, until to-day practically all of the converting of copper mattes is in basic-lined converters.

The principle of the basic lining is very simple and clear: namely, the use of a chemically basic material, in order to avoid chemical action between the lining on the one hand, and the charge and the products of the process, which are also basic, on the other. The necessary acid (silica) to carry on the chemical reactions is supplied by introducing siliceous ores, or other materials, into the converter, either through the mouth or through the tuyeres.

Although magnesite and other materials had been tried experimentally at the Boston and Montana Reduction Works at Great Falls, basic lining was not introduced permanently until Mar. 9, 1911, after it had been in use for a time at Baltimore, Garfield, and Anaconda.

The usual practice to-day is to use a magnesite-brick lining in the shell, varying from 9 to 30 in. in thickness in different parts of the converter, the thickest lining being at the tuyeres, on account of the intense chemical action and the high temperature at that point.

Unless the temperature is allowed to become too high there should, from a chemical point of view, be no corrosion of the lining. However, the converting process does not maintain a uniform temperature in the converter, the heat evolved from the chemical reactions being different at different stages of the process; and further, the process is an intermittent one, a charge being introduced, finished, and poured out of the converter, and then a fresh charge introduced, the result being varying temperatures, the extreme low temperature occurring in the interval between pouring one charge and introducing the next. These variations of temperature cause the brick to crack and spawl and break off, tending to thin the lining in places.

Again, if the temperature is allowed to become too high the brick become soft, and then mechanical wash and abrasion wear off the lining. This latter wear takes place under normal working condi-



tions, but not to the same extent as when the temperature is too high. Thus the theoretically indestructible lining is not practically so.

In order to guard against this wear and protect the brick it was the practice to heat the newly lined converter to a bright red heat with wood, coal, oil, or other fuel. When it had been brought to the proper temperature a charge of matte was blown to white metal in another converter and this white metal charged to the new converter, and then blown to copper, thus coating the lining with a thin layer of white metal and copper. This operation was repeated several times before the converter was considered ready for the regular service of blowing matte. This did not give very satisfactory results, as the melting point of the white metal and copper was low and any slight increase over the normal working temperature would result in melting off this coating, exposing the brick, which would then wear away. That this is not a satisfactory method is attested by the fact that there have been many basic linings which have lasted only a few days, whereas basic linings properly protected, as described later, have lasted over two years and are still in service.

We very soon deviated from this method of preparing a new converter to the practice of immediately blowing matte, blowing the charge for a few minutes until the temperature approached a dangerous point, then allowing the charge to stand for 15 or 20 min., then repeating the treatment, and continuing this cycle of operations until the brick had become coated with a layer of matte. This was just as good as the white metal treatment, and better from the point of view of doing away with the transfer of white metal.

#### *Monolithic Magnetite Lining or Coating.*

This method of protecting the brick lining of a converter is based on the fact that magnetite<sup>2</sup> is formed in artificial magmas, especially where the proportion of silica is low. Any excess of iron over that needed to combine with silica is likely to be deposited in the form of magnetite.

The melting point of magnetite is given by various authorities as from 1,527° to 1,588° C. The ordinary working temperature in a converter will rarely go over 1,200° C. unless improperly operated. It will be evident that, if we have a basic coating or covering over the brick lining, which coating has a melting point greater than that of the charge, and which can be put on at will during the process of

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<sup>2</sup> Data of Geochemistry, *Bulletin No. 491, U. S. Geological Survey*, p. 327 (1911).

the blow, once a converter is lined, it should never be relined. This would be the case if 100 per cent. efficiency were possible.

The method of applying this lining to converters is as follows: The newly lined shell is heated up gradually to a bright red heat and charged with liquid matte, preferably of a low grade, say 35 per cent. The charge of matte is blown for 10 or 15 min., when the addition of cooling material will be found necessary, on account of the increase in temperature in the converter. The cooling is performed by the addition of cold matte. Alternate blowing and the addition of cold matte is continued until the charge is blown to white metal. No ore or other siliceous material has been added thus far in the blowing of the initial charge of matte, and therefore, with the lack of silica, the conditions have been right for the formation of magnetite.

It will now be observed that the interior of the converter has become coated with the magnetite formed during the blow. A fresh charge of liquid matte is added, together with a little less than the requisite amount of silica, and blowing is continued in the regular way until the brick lining is thoroughly coated and no brick is exposed. After this the actual silica required to flux the iron is used.

Under these conditions the lining should last a very long time, as the coating can be maintained by proper regulation of the converting temperature and the siliceous charge.

Should the coating become too thick, the silica of the charge can be increased, as well as the temperature, and a portion of the coating removed; and *vice versa*, in case the coating wears off and the brick becomes exposed.

In the blowing of the matte without ore, the iron becomes oxidized to  $\text{Fe}_2\text{O}_3$ , and the sulphur to  $\text{SO}_2$ . The working temperature of the converter can be kept down to normal by adding cold matte, converter cleanings, scrap, or ore, the material used depending on the operating conditions of the charge.

A detailed record of the basic converter practice at Great Falls up to June 1, 1913, is given in a previous paper.<sup>3</sup> The following table, containing parts of Table IV of the paper referred to, brings this information up to date.

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<sup>3</sup> Wheeler and Krejci: Great Falls Converter Practice, *Bulletin* No. 80, August, 1913, pp. 1861 to 1869.

*Record of Basic-Lined Converters.*

| Converter. |         | Campaign.      |               | Elap-<br>sed<br>Days. | Tons<br>Cu. | Charges. | Tons<br>Cu per<br>Charge. | Total Time<br>Operating. |      |
|------------|---------|----------------|---------------|-----------------------|-------------|----------|---------------------------|--------------------------|------|
| Class.     | Bottom. | From.          | To.           |                       |             |          |                           | Hr.                      | Min. |
| IV.        | B       | Mar. 9, 1911   | June 3, 1912  | 451                   | 12,216.1    | 1.026    | 11.9                      | 7,509                    | 45   |
| IV.        | C       | Apr. 29, 1911  | Jan. 4, 1912  | 251                   | 7,479.1     | 590      | 12.9                      | 4,149                    | 40   |
| IV.        | D       | May 7, 1911    | Oct. 9, 1913  | 886                   | 17,246.3    | 1,814    | 13.1                      | 9,756                    | 35   |
| IV.        | A       | June 22, 1911  | Oct. 15, 1913 | 846                   | 20,331.4    | 1,448    | 14.0                      | 9,986                    | 15   |
| c III.     | S       | Nov. 16, 1911  | Dec. 25, 1912 | 406                   | 8,990.7     | 640      | 14.0                      | 4,523                    | 50   |
| IV.        | C       | Mar. 17, 1912  | Apr. 13, 1913 | 392                   | 5,643       | 445      | 12.7                      | 2,960                    | 10   |
| V.         | A       | Aug. 8, 1912   | Dec. 17, 1912 | 137                   | 2,836       | 88½      | 32.4                      | 656                      | 45   |
| δ IV.      | B       | Sept. 12, 1912 | Aug. 2, 1913  | 325                   | 4,538.2     | 356      | 12.7                      | 2,485                    | 10   |
| δ V.       | A       | Jan. 20, 1913  | Aug. 28, 1913 | 219                   | 8,981.9     | 252.58   | 35.5                      | 2,122                    | 15   |
| c III.     | S       | Mar. 28, 1913  | June 1, 1913b | 70                    | 404.2       | 33       | 12.3                      | 251                      | 50   |

b Still running on this campaign.

c These two runs are really parts of the same campaign. The converter was shut down on Dec. 25, 1912, to change the tuyeres for experimental purposes.

During October, 1913, all of the Class IV or 12-ft. converters were abandoned, the plant reaching that point in reconstruction where the new 20-ft. converters were used entirely. All the converters referred to in the preceding table as operating in October, 1913, were abandoned while still in operating condition.

If it is desired to learn the performance of the converters listed above in terms of matte treated, the "Tons Cu" should be multiplied by 3.2. The result will be approximately the tons of matte treated.

We believe these figures show greater duty per lining than other basic-lined converters, and we attribute it primarily to the monolithic magnetite lining, properly handled. We even believe that it will be possible to use a cheaper original lining than the magnesite and have made some experiments along that line, but it has not yet been demonstrated to our satisfaction.



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Feb. 1, 1914.

## The Generation of Steam by Waste Heat from Furnaces.

BY F. PETER,\* LEOBEN, AUSTRIA.

TRANSLATED BY R. W. RAYMOND, SECRETARY EMERITUS.

(New York Meeting, October, 1913.)

### I. GENERAL INTRODUCTION.

TECHNICAL progress takes place in two directions: the improvement of methods, affecting the quality of the product; and increase in the economy of operations, affecting its cost. In the iron-industry, practice is pretty well settled, and revolutionary changes of method are, for the present, not to be expected. Hence, in this industry, the principal endeavor is to reduce costs by the use of labor-saving inventions, such as the machines brought into use during the last decade. But it is not alone necessary to reduce the labor-cost; complete economy requires also a saving in raw material. Under this head we may rank the coal employed as metallurgical fuel; and it follows that progress includes the economic use of fuel, so managed as not to injure quality of product. In the present paper it will be shown how, by suitable utilization of the heat from the furnace, a large portion of it may be made available for other purposes.

Such utilization of waste-gases is important in all industries which employ furnaces (especially heating- and smelting-furnaces); and in the first rank of these stand the iron-, glass-, and porcelain-manufactures. The following pages are devoted chiefly to the waste-gases of smelting-works, and especially to those reverberatory-furnace gases which are not combustible.<sup>1</sup>

The object of metallurgical furnaces is either to fuse the material charged or to bring it to a high temperature required for further mechanical manipulation. Leaving out of consideration for the present the reverberatory fusion-furnaces, we have to do with the heating-furnaces employed in connection with rolls, hammers, or hydraulic presses. The temperature to which the material must be

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\* Professor at the Royal Imperial Mining Academy of Leoben, Austria.

<sup>1</sup> For more thorough discussion, reference is made to the work of the present writer, *Die Abhitzekessel*, published in 1913 by W. Knapp at Halle an der Saale.

raised in such furnaces varies, according to quality and use of product, from  $800^{\circ}$  to  $1,200^{\circ}$  C., and, of course, the hearth itself must be still hotter, as will be also the gases coming from the hearth (except in the continuous heating-furnace). It follows that the efficiency of such a furnace with respect to the utilization of fuel must be very low, as will appear from the following statement of the matter.

If  $t_a$  and  $t_e$  be the temperatures at the beginning and the end of the hearth, respectively,  $\eta_1$ , the theoretical ratio of utilizable heat, will be  $\eta_1 = \frac{t_a - t_e}{t_a}$ . For instance, if the initial temperature be  $1,400^{\circ}$  C., and the final temperature  $1,000^{\circ}$  C., the percentage of available heat will be  $\frac{1,400 - 1,000}{1,400} = 0.29$  or, roughly, 30 per cent. This calculation makes no allowance for the great loss of heat by radiation and conduction, which will be discussed hereafter.

In the instance given, on the assumption that there was no suction of air through the doors, the combustion-gases have lost, on the way from fire-bridge to flue, say 30 per cent. of their original heat, and there should remain, therefore, some 70 per cent. of the heat generated on the grate, to be made available (if it be possible to cool the gases to  $0^{\circ}$  C., or to the temperature of the outer air, as the case may be).

The simplest way to utilize this heat would be to prolong the furnace, and move the charge towards the fire, so as to heat it on the counter-current principle. By this method it is possible in the continuous heating-furnace to operate the furnace itself at a lower temperature, thus securing additional fuel-economy. Of course it is not the difference between initial and final temperatures only, but, as already observed, all incidental losses of heat also, which must be considered in maintaining the efficiency of the furnace. Making allowance for the great losses by radiation, which depend upon the temperature of the furnace, one soon arrives at a practical limit of furnace-size, beyond which it is not advantageous to go. The lower the flame-temperature at the end, the greater the efficiency of the furnace.

As to further reduction of chimney-temperature, however, it must be inquired whether the draft may not be thereby diminished. Theoretically, the maximum draft is obtained at about  $300^{\circ}$  C. of gas-temperature. An example will show how the draft is affected by higher or lower temperatures.

Let us assume that the stack of such a furnace has a draft of

20 mm. water-column, one-half of which is used in overcoming the resistances in the furnace and flue, and on the grate, leaving 10 mm. to affect the speed of the escaping gases. In order to determine the volume or weight of the gases drawn per unit of time through a stack of say 1 sq. m. area, we will consider three cases, assuming the gas-temperature at 200°, 300°, and 400° C. respectively.

Under the conditions assumed, the friction in the stack itself being neglected, we have  $v = \sqrt{2gh}$  for the velocity of the gases entering the stack with an effective draft-pressure of 10 mm. water. Substituting for the water-column  $h_w$  the corresponding air-column in millimeters,  $\gamma$  being the specific gravity of the chimney-gas and  $\gamma_w$  that of water, we have  $\sqrt{2gh_w \frac{\gamma_w}{\gamma}}$  as the velocity of the chimney current. At the given temperatures, the specific gravities of the chimney-gases are approximately :

| Temperature.<br>Degrees C. | Value of $\gamma$ in Kilograms<br>per Cubic Meter. |
|----------------------------|----------------------------------------------------|
| 200                        | 0.7                                                |
| 300                        | 0.6                                                |
| 400                        | 0.5                                                |

Calculated upon these figures, the respective velocities of the chimney-gases in the three cases will be roughly 16, 18, and 19 m. per second; and the weight of gas passing per second through the assumed cross-section of 1 sq. m. (no allowance being made for resistance in the stack) will be roughly 12 to 10 kg. at these three temperatures. It appears at first sight that the weight of gas actually moved by the stronger draft is not greater, but, on the contrary, somewhat smaller. But this contradiction is not real; for we have assumed the absence of frictional resistance in the stack, whereas, this resistance not only exists, but may be confidently assumed as greater for the cooler, and smaller for the hotter (*i. e.*, lighter) gas-current. The safe practical conclusion is that, within certain limits, the weight of gas drawn through a chimney remains constant under moderate increase or diminution of temperature. It follows likewise, that a considerable cooling of the gases for utilization of their surplus remaining heat cannot injure the process of combustion, provided the draft in the chimney is strong enough to overcome resistances, and produce the necessary gas-velocity. In most cases, the chimney-draft has to be throttled anyhow; and in cases where blast-pressure (*Unterwind*) is used, there is no room for any fear of disadvantage through reduction of draft.

The temperature of the waste-gases, though varying with the pur-

pose for which the furnace is operated, is usually high enough for the utilization here to be described. According to the method of calculation employed above, the available heat in gases leaving the furnace at  $1,000^{\circ}\text{C.}$  and entering the chimney at  $300^{\circ}\text{C.}$  would be  $\frac{1,000 - 300}{1,000}$  or 70 per cent.; that is, under the conditions assumed, about 70 per cent. of the heat of the gases leaving the furnace should be available for other purposes. As a general rule, however, this figure is not reached, because, for reasons of construction and imperative considerations of safety, the boiler which is to be heated by the waste-gases must not be directly a part of the furnace construction, and hence a fall of temperature will take place in the connecting main. Assuming in our example such a fall of  $100^{\circ}\text{C.}$ , we have, as the available percentage of heat,  $\frac{900 - 300}{1,000}$  or, about 60 per cent.

It is evident at once from this discussion that *the arrangement of furnace and boiler should be such as to involve the smallest possible fall of temperature between the two.* Long mains are therefore to be avoided as far as practicable, since they involve a considerable relative fall of temperature. Fortunately there are many constructions which, in most cases, satisfy the requirements above stated.

The total theoretically available heat-energy of the coal burned on the grate is

$$\eta = \frac{t_a - t_e}{t_a} + \frac{t'_a - t'_e}{t_a}$$

the flame-temperature being  $t_a$  at the beginning and  $t_e$  at the end of the hearth;  $t'_a$  initial, and  $t'_e$  final, temperature of the waste-gases. And since (apart from losses between furnace and boiler)  $t_e = t'_a$ , the formula becomes

$$\eta = \frac{t_a - t'_e}{t_a}$$

In the example given,  $t_a = 1,400^{\circ}\text{C.}$ ;  $t_e = t'_a = 1,000^{\circ}\text{C.}$ ; and  $t'_e = 300^{\circ}\text{C.}$  Hence,

$$\eta = \frac{1,400 - 300}{1,400} = 0.79$$

whence it appears that by the addition to a heating-furnace of a boiler heated by waste-gases a total theoretical availability of nearly 80 per cent. would be realized, about 30 per cent. being contributed by the furnace and 50 by the boiler. *The theoretically possible utilization of*



*heat is thus essentially higher in the boiler than in the furnace therewith connected.*

So far we have not considered the various losses in the furnace and at the boiler. But they must necessarily receive attention, since only so can the increase of economy produced by adding to a heating-furnace a suitably constructed waste-gas-heated boiler be placed in the right light.

The modern rolling-mill furnaces, directly fired or with half-gas firing, combine with a maximum of work a utilization of the heat of the gases amounting in certain favorable cases to perhaps 15 or even 20 per cent. Assuming for less productive furnaces an economic degree (*Wirkungsgrad*) of only 10 per cent. (by which is meant the relation between the heat actually utilized in warming the ingot or bloom and the total heat generated on the grate), it appears that of the 30 per cent. available for this work (according to the calculation in our example) only one-third is really brought out. The remaining 20 per cent. of the total heat generated we must regard as lost through radiation and conduction, as well as through incomplete combustion.

The loss by radiation and conduction of a quantity of heat greater than the quantity utilized is an extreme but conceivable case, in view of the high temperatures occurring within the furnace. According to Stefan-Boltzmann,<sup>2</sup> the transfer of heat by radiation varies as the fourth power of the absolute temperature of bodies concerned.

In a boiler of proper dimensions and construction, the conditions are essentially more favorable, since here only the loss by radiation makes itself felt to any considerable extent. Assuming a total boiler-loss of 15 per cent. of the theoretical boiler-efficiency, we shall have, notwithstanding, in our example, an actual realization of 85 per cent. of the available 60 per cent., or about 50 per cent. *Thus, by the addition of a properly constructed boiler to a heating-furnace, the utilization of the fuel-energy may be raised from 10 per cent. to 60 per cent., whence it is again clear that such an addition is imperatively demanded in the interest of furnace-economy.*

Thus far, we have left out of consideration the fuel and the conduct of combustion. But in the operation of the reverberatory, it is, as already observed, necessary not only to maintain the furnace-temperature required by the pieces to be heated, but also, in many cases (particularly in furnaces heating "quality"-steels), to keep the composition of the gases in the furnace such as to exclude, as far as possible, any deleterious action upon the charge, which it must be our

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<sup>2</sup> *Stahl und Eisen*, vol. xxxi., No. 40, p. 1640 (Oct. 5, 1911).

aim to protect, not only against overheating, but also against too great oxidation. The flame should carry as little excess of air as possible; so that it seems in many cases better to work with too little than with too much air. In the former case, there would be a loss of unconsumed gases; but this would ordinarily be smaller than the loss occasioned in the latter case by the burning of expensive material in the charge.

The amount of loss from incomplete combustion depends chiefly on the construction of the furnace and the manner of firing. Investigations of this question made by the present writer have given various results, so that (as might, indeed, have been expected after the foregoing statements) no generally applicable figures can be given. In one experiment, no less than 6 per cent. of CO was found in the waste-gases of a furnace heating large blooms. In the very great majority of cases the furnace could be run with, perhaps, from 2 to 3 per cent. of carbon monoxide in the waste-gases, so as to avoid excessive burning of the charge. This loss through imperfect combustion has been omitted from the foregoing discussion because, being so highly dependent upon various working-conditions, it cannot well be expressed in a general formula. That such losses are not exceptional, has been shown by Dr. M. Philips,<sup>3</sup> who found in the waste-gases from a half-gas furnace more than 9 per cent. of carbon monoxide, and also a considerable amount of hydrogen.

Before considering in detail the several kinds of waste-gas boilers, we should inquire why the production of steam is relatively the simplest and easiest, and also commercially the most profitable, way of utilizing the heat of such gases. The other ways which have been proposed are: Preheating the charge; preheating the air for combustion; and preheating the boiler-feed, or superheating the steam, of boilers directly fired.

The preheating of the charge in continuous heating-furnaces has been mentioned already; and it has been shown that there is a practical limit, beyond which the furnace cannot be advantageously lengthened for this purpose.

The heat of the waste-gases is applied satisfactorily to the preheating of air in half-gas furnaces, and of air and gas in gas furnaces.

For advantageous preheating of the boiler-feed, the difference in temperature between the escaping gases and the water to be thus treated is too great. The intensive heating of an ordinary amount of water would absorb but a small quantity of heat, and consequently

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<sup>3</sup> *Stahl und Eisen*, vol. xxxii., No. 1, p. 13 (Jan. 4, 1912).

a large quantity of heat would not be utilized, unless much more water were preheated than is called for in such establishments.

It would be easy to superheat steam by means of the waste furnace-gases. Not to mention the fact that the economic result might leave much to be desired, this method of utilizing the hot gases is open to a serious objection, namely, that the operation of the furnace does not uniformly correspond with the consumption of steam. It might happen, for instance, when the engines of the works were using but little steam, that what they received would be too hot; or, on the other hand, when the several engines happened to be all working at once, and thus taking a large aggregate of steam, it might not be sufficiently superheated.

Yet this method is occasionally practiced. At one of the works of the U. S. Steel Corporation<sup>4</sup> a large central superheater was installed, for raising to 240° C. the temperature of 110,000 kg. of steam per hour, at a pressure of 10 atm. This apparatus received the waste-gases from four ingot-heating furnaces and superheated the steam for four roll-trains, requiring a total of 8,000 h-p. Whether such an arrangement can satisfactorily utilize the heat of the chimney-gases may be doubted, especially in view of the fact that in superheating steam, there must be, to secure a satisfactory efficiency per unit of heating-surface, a very great difference of temperature between the heat-giving and the heat-receiving material. If the transfer of heat per square meter of heating-surface is large, then the temperature of the gases leaving the superheater will be high—and *vice versa*.

*The heat of waste furnace-gases can be most economically utilized in the production of steam.* Steam is used everywhere and always in metallurgical works. Even those which are run throughout by electric power, derived from gas-engines, are provided with steam-boiler plants at least as a reserve, or for use in special operations. By contributing to the general steam-conducting system the steam generated by the heat of waste-gases, the work, and therefore the fuel-consumption, of the directly-fired boilers is diminished. Moreover, the difference of temperature between the hot gases from the furnace and the water under steam-pressure in the boiler is about the same as between the flame and the water in a boiler directly fired, so that the transfer of heat will be as satisfactory in the former case as in the latter.

One objection may be raised. It is well known that the operations of furnace and boiler do not continuously correspond. The times of maximum production of steam by means of the furnace-gases are not

<sup>4</sup> *Scientific American Supplement*, Sept. 9, 1911, p. 169.

always those of the greatest consumption of steam from the boiler. But this circumstance will very seldom be important enough to impair the economy of the method. For, on the one hand, steam is almost always in use somewhere in the plant, and, on the other hand, boilers containing a considerable quantity of water are quite capable of storing temporarily a considerable quantity of heat—especially when (as is almost always the case) the steam-pressure is below the normal.

It may be added that in modern construction the proportion of size between furnace and boiler is very good, so that the two can exist side by side, without making the boiler awkwardly large. A comparison of the heat which can be developed by 1 sq. m. of grate-surface with that which can be taken up by 1 sq. m. of boiler heating-surface, shows that the boiler need be only about as large as the furnace, or, in some cases, may be even smaller.

## II. PRINCIPLES GOVERNING THE CHOICE OF A BOILER-SYSTEM.

The first boilers built for this purpose combined economy of ground-space in the works with the direct upward discharge of the spent gases. The vertical cylinder-boiler stood, as it were, in the enlarged lower portion of a chimney, the hot gases played around it up to a given height, and were there taken up, generally by two diametric sheet-metal flues, at the side of the boiler, and conveyed away, upward. The vertical cylinder-boilers had generally a diameter of from 1 to 1.2 m., and a total length of 12 or even 15 m.

This type, often employed in the '60's of the last century, had two advantages: (1) it occupied, together with the surrounding masonry, only about 6 to 8 sq. m. of ground-space; and (2) its chimney was combined with it—a welcome feature from the standpoint of furnace-management, because it assured the complete independence of each furnace. This form of boiler presents, however, such weighty disadvantages that its use is no longer seriously considered. A very questionable improvement, was the vertical flame-tube boiler of Hall.

Gradually, the consideration of ground-space gave way to that of safety, and horizontal boilers, which could be more easily shut off, were placed behind the furnaces. The so-called Bouilleur boilers (cylinders, with one or more boiling-tubes [*Sieder*]) were first used, and afterwards came fire-tube boilers. These types permitted, through the establishment of a direct connection between furnace and chimney, the operation of the furnace with the boilers cut out of the system; and thus assured a greater safety. The development of heating-surface easily followed, since wide limits were provided for it. The

degree of utilization—in other words, the amount of steam power produced—per kilogram of furnace-coal was greatly advanced by the use of the fire-tubes; the boilers were much more easily served and cleaned than the vertical ones; in short, this would have been recognized as the ideal form for a waste-heat boiler, if it had not demanded such a disproportionate ground-space. While a simple puddling- or heating-furnace occupied, say, from 16 to 20 sq. m., the accompanying fire-tube or Bouillier boiler called for from 20 to 40 sq. m., or almost twice as much as the furnace itself.

The necessary ground-area is smallest when the boiler is placed over the furnace. If it occupies not more, or not much more, horizontal area than the furnace, the question of space retires completely into the background, and the furnace can be designed to suit the conditions of operation with a freedom previously unknown, since furnace and boiler can now be regarded as a coherent whole. This conception seems to have taken tangible form first in America, where water-tube boilers were placed above and behind puddling-furnaces. But in designing such overhead boilers, the special kind and operation of the furnace must be kept in mind. A furnace within which the highest temperatures prevail suffers from these, or through the consequent expansion of its refractory material, certain changes, which the strongest armature cannot prevent. These movements or changes of form must be absolutely kept away from the boilers above; otherwise, the position of the boilers would be altered in the course of time, with a certain lack of safety in operation as a natural result. Nor should it be forgotten that a furnace, according to the demands made upon it, will have to be rebuilt much sooner than a boiler, even when the latter is placed over it. Though furnace and boiler constitute an almost indivisible whole, they must be built separately, so that changes suffered by the furnace may not be communicated to the masonry of the boiler, and thus to the boiler itself. This requirement is satisfied by mounting the boiler upon independent cast- or wrought-iron columns, placed at a certain distance from the furnace-buckstays. The use of these boiler-columns as part of the armature is, for the reasons just given, not permissible. They can be in each case so grouped around the furnace as not to hinder its operation. In many instances the structure thus carrying the boiler may serve as a support for door-levers, etc.

The question of total height for furnace and boiler plays no part in modern plants. Even in extreme cases, the highest part of the boiler would be scarcely 7 m. above the furnace-floor; whereas the traveling-cranes in modern works run on a still higher level.

The relative position of boiler and furnace having been determined, the next question concerns the kind of boiler which will involve the least interference with furnace-operations, while possessing the maximum technical efficiency, and not requiring too much in the way of attention and maintenance. Of the various boilers claiming consideration, we may name the fire-tube, the combined fire- and smoke-tube, the water-tube, and the boilers of locomotive and locomobile form. All of these are more or less suitable for the purpose in view, and it will require special study in each case to decide which should be adopted.

One fundamental difference among them is, that the flame-tube and water-tube boilers require to be set in masonry, while the other types named can do without it, since only their interior surfaces are played upon by the hot gases. In consequence of this masonry-setting, boilers of the first-mentioned types sometimes seem somewhat large and clumsy, as compared with the furnaces, whereas the boilers which have interior firing exclusively look much more graceful and small, as indeed they are, since they have, instead of the thick masonry setting, a sheet-metal case encircling them at a small distance. Behind this, the non-conducting material lies upon the mantle of the boiler. By reason of the smaller size of this type of boiler, its use affords some advantages in the better lighting of the works.

### III. RECENT WASTE-GAS BOILERS FOR DIRECTLY-FIRED HEATING-FURNACES.

Fig. 1 shows in section the usual arrangement of a fire-tube boiler above the furnace, as executed by the Deutsche Hüttenbaugesellschaft (the German Furnace-building Company). The hot gases from the furnace traverse first the fire tubes, then a superheating chamber, and then return along the floor and on both sides of the boiler, to be finally conveyed by a sheet-metal flue to the chimney.

A required cutting-off of the furnace from the boiler is effected by the slide *s*, which, in a properly constructed apparatus, could scarcely give occasion for disturbance. When the valve is closed, the hot gases pass from the furnace through the opening *a*, Fig. 1, into a masonry pier, under the sheet-metal flue, and through this to the chimney-flue, which is lined for a short distance with refractory material.

Where the gas or flame enters the fire-tube, the precaution should be taken of providing the first section—say from 1 to 1.5 m.—of the latter with a refractory lining, to avoid injury to the boiler from impinging jets of flame.

Experiments covering more than a month with a furnace of this kind, built for a rolling-mill, gave, according to the above-named furnace-building company, the following results:

|                                                                      |             |
|----------------------------------------------------------------------|-------------|
| Heating-value of the coal-mixture in its original condition.....     | 6,192 h. u. |
| Heating-value of the coal-mixture in air-dried condition.....        | 6,763 h. u. |
| Heating-surface of the boiler.....                                   | 80 sq. m.   |
| Water evaporated by 1 kg. of coal burned on the grate.....           | 2.71 kg.    |
| Average evaporation of the boiler per hour for 1 sq. m. surface..... | 12 kg.      |
| Coal-consumption for 100 kg. of pieces, charged cold.....            | 10.1 kg.    |
| Total weight of pieces charged per shift.....                        | 42,000 kg.  |

In order to determine separately the parts played by furnace and boiler in utilizing the heat from the coal, each must be considered by itself.

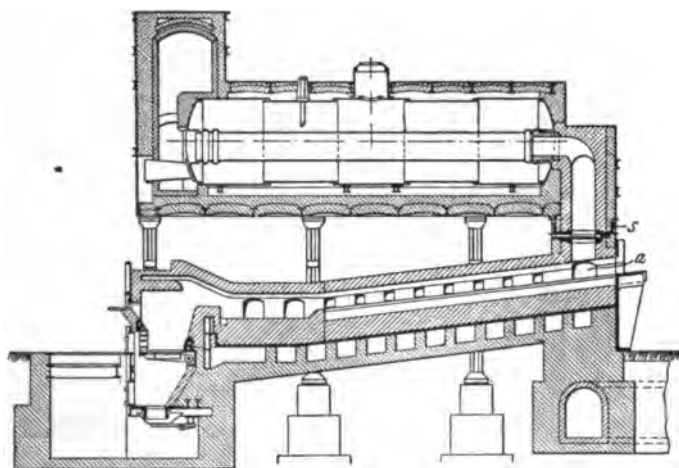


FIG. 1.—SECTION THROUGH FURNACE AND OVERHEAD FLAME-TUBE BOILER OF THE GERMAN FURNACE-BUILDING CO., DÜSSELDORF.

On the assumption of a complete combustion, there were generated about 68,000 h. u., of which, in round numbers,  $100 \times 0.168 \times 1,100 = 18,000$  h. u. were transmitted to the pieces heated. The utilization of heat in the furnace was therefore about 26 per cent., while about 17,000 h. u., or 25 per cent., were consumed in the production of steam. The total heat-utilization was therefore about 51 per cent. These figures have approximate value only, since the temperature of the material as charged and as withdrawn was merely estimated.

If the calculation be pursued further, and 10 per cent. of  $\text{CO}_2$  be assumed in the gas at the end of the boiler (after complete combustion), it is found that there is a loss of about 19 per cent. in the gases escaping at about  $300^\circ \text{C}$ . from the boiler. Hence the loss by radiation, conduction, and unburned residues is  $100 - 51 - 19 = 30$

per cent. That is to say, the loss by radiation, conduction, etc., for both furnace and boiler, is 30 per cent., of which about three-fourths is to be charged to the furnace, and one-fourth to the boiler.

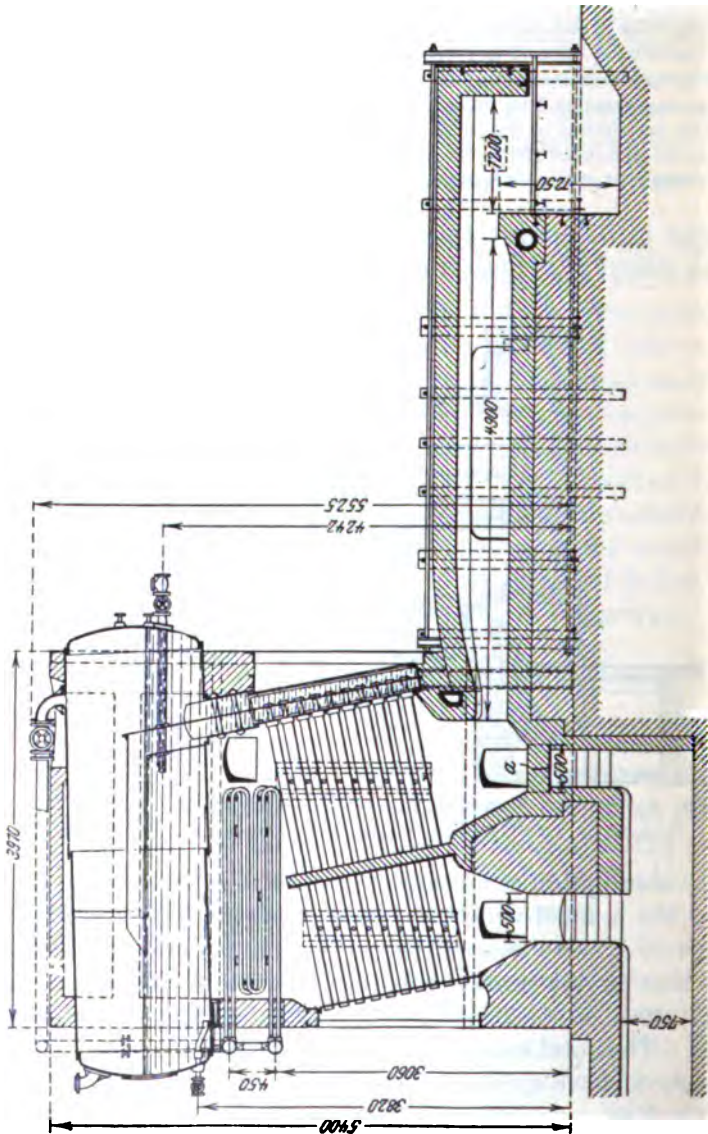


FIG. 2.—JOINT-CONSTRUCTION OF FURNACE WITH WASTE-HEAT BOILER. DÜRR TYPE.

The furnace in Fig. 1 having a long hearth *per se*, there is no discrepancy of size between furnace and boiler; but in the case of a smaller furnace, this boiler (a 2-fire-tube boiler, from 8 to 9 m. long) would seriously over-balance the furnace, or else the boiler would



have to be shortened, with a considerable diminution of heating-surface. But in the presence of a large quantity of gas at high temperature, the heating-surface must be correspondingly large, in order to convey a large amount of heat to the boiler-water. This circumstance has led to the adoption of water-tube boilers, which permit for a given ground-area a great development of heating-surface, and are adapted to the highest steam-pressures.

Fig. 2 shows the combination of a furnace with a Dürr water-tube boiler placed partly over and partly behind it. Since, in this instance, the available space was not sufficient for water-tubes of the normal length of 5 m., it was determined to use a boiler containing several sets of tubes, 3 m. long, and placed over one another, and, moreover, to provide for two passes only, so that the hot gases ascending in the first pass would flow along the superheating-pipes (which were built into the masonry) and the lower part of the boiler-mantle, and then return downward, around the bundle of water-pipes, to the chimney-flue. The possibility of cutting off the boiler from the furnace was, at least partly, secured in this arrangement by building into the wall under the first pass a Schlitz sliding-plate (*a*, Fig. 2), which, during the normal operation of the furnace, is protected by a layer of sand from the direct action of the fire. This does not effect a complete separation of furnace and boiler; but it permits the waste-gases, in case of need, to be drawn, under the first pass, directly into the chimney-main.

Thorough experiments with this boiler occupied 11 days, during which the furnace heated by day the pieces for the rolling-mill (which was not at that time running at night). During the night-shift, the furnace was merely kept warm. The measurements and results were as follows:

|                                                                                        |              |
|----------------------------------------------------------------------------------------|--------------|
| Grate-area of the furnace.....                                                         | 1.9 sq. m.   |
| Hearth-area (width, 1.8 m.).....                                                       | 8.2 sq. m.   |
| Ratio of grate-area to heating-surface of boiler.....                                  | 1:48         |
| Coal-consumption per sq. m. grate-area for each hour of the working period, about..... | 200 kg.      |
| Average evaporation per sq. m. and hour, as above.....                                 | 13 kg.       |
| Maximum evaporation per sq. m. and hour, as above.....                                 | 17 kg.       |
| Average heating-value of the coal-mixture, about.....                                  | 4,900 h. u.  |
| Average steam-pressure.....                                                            | 5 atm.       |
| Average steam temperature.....                                                         | 270° C.      |
| Superheating.....                                                                      | 112° C.      |
| Water evaporated by 1 kg. coal.....                                                    | 3.15 kg.     |
| Corresponding heat utilized from 1 kg. coal in evaporation, about...                   | 2,170 h. u.  |
| Efficiency of the boiler, about.....                                                   | 44 per cent. |

As the above figures show, the conditions of operation with this type of boiler-construction were very favorable to a high efficiency. But the union of furnace- and boiler-masonry had a bad effect, causing, in the latter, cracks, dislocations and bulges, which increased the frequency of necessary repairs. Moreover, the longitudinal buck-stays of the furnace left much to be desired.

Fig. 3 shows a Dürr boiler, with 120 sq. m. of boiler heating-surface, and 24 sq. m. of heating-surface in the superheater, the whole supported, upon a separate frame of rolled iron above a large ingot-heating furnace, the hearth-area of which is about 10 sq. m.

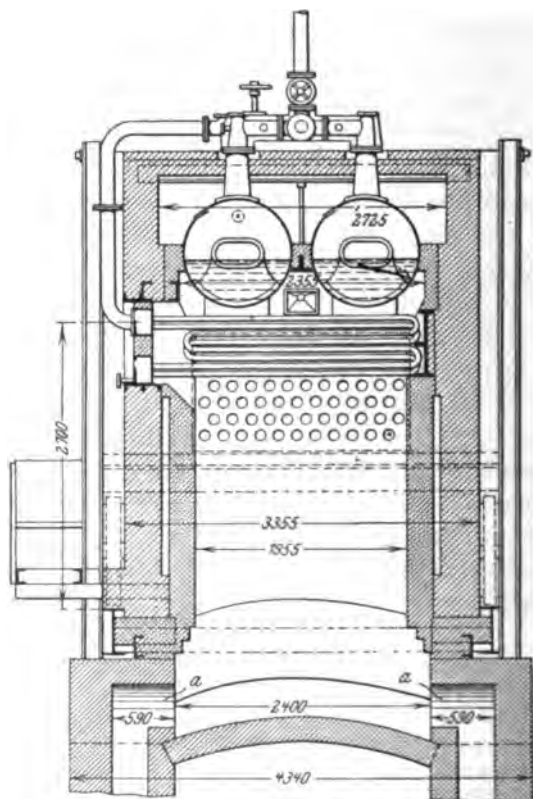


FIG. 3.—WASTE-HEAT BOILER, DÜRR TYPE, OVER LARGE INGOT-HEATING FURNACE.

These boilers, which have been running satisfactorily for about six years, produce per hour per square meter of heating-surface about 11 kg. of steam at  $280^{\circ}$  C. The furnace-gases enter through two openings (*a, a*, Fig. 3) to the boiler, go in three passes over the water-tubes, and then escape into the atmosphere through a sheet-metal

pipe placed between two boilers and carried by the boiler-masonry. Any necessary shutting-off of boiler from furnace is made possible by a fire-proof chimney-flue under the floor of the works, with which the openings *a, a*, are connected, and which is ordinarily closed by a slide, so as to permit the normal circulation of the gases to the boiler.

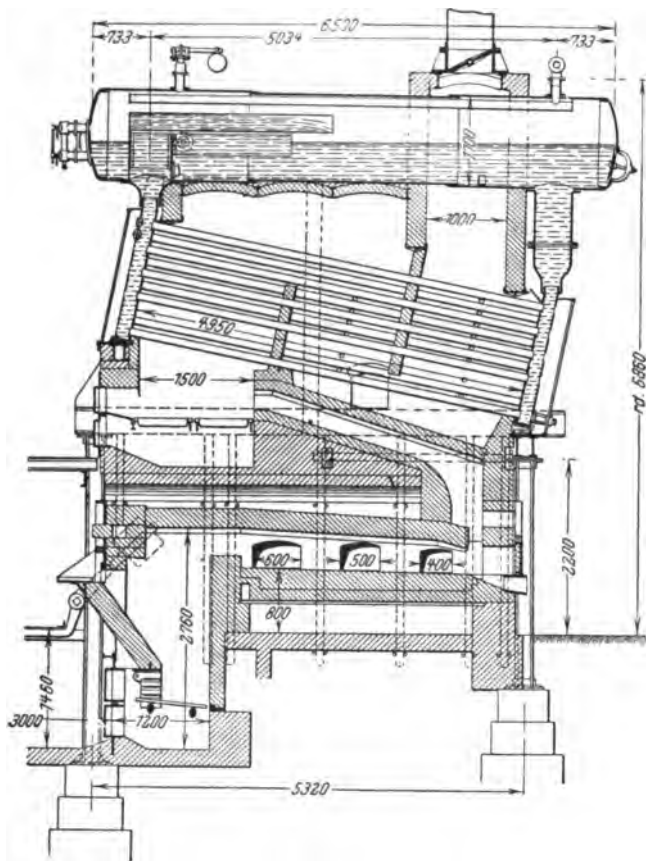


FIG. 4.—WASTE-HEAT BOILER, DÜRR TYPE, OVER SMALL HEATING-FURNACE.

Fig. 4 represents a Steinmüller boiler, with 82.5 sq. m. of heating-surface, and provision for auxiliary direct firing, carried upon a frame over a small heating-furnace. According to the builders, this boiler, heated with the waste-gases only, produces up to 15 kg. of steam per square meter of heating-surface, per hour. With the aid of the auxiliary grate, the product is from 20 to 25 kg. This combination of gas-heat with direct firing is no doubt due to the desire to get as much steam as possible out of the boiler, incidentally utilizing the heat of the waste-gases, and also diminishing the cost of the in-

stallion per unit of steam-production. But the objection cannot be disregarded, that a separately located and separately heated boiler costs considerably more for attendance than one which constitutes a unit in a battery.

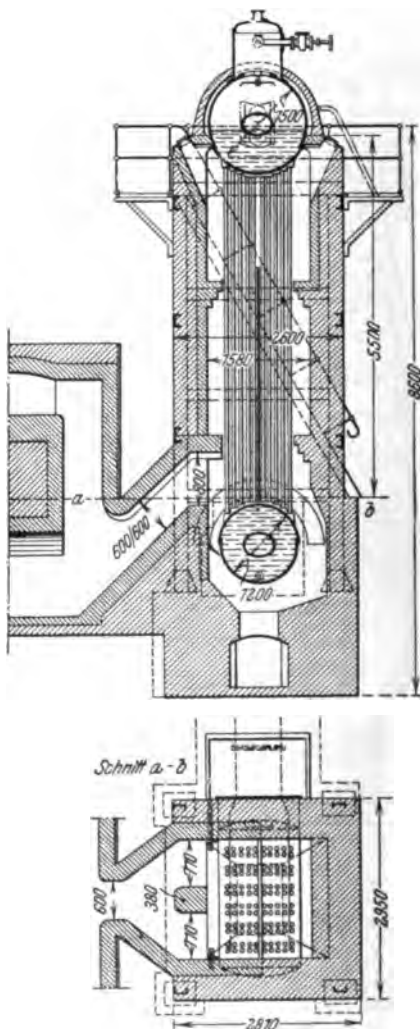


FIG. 5.—GARBE WASTE-HEAT BOILER, COMBINED WITH REVERBERATORY FURNACE

The steeply inclined or vertical tubular boilers (*Steilrohrkessel*), so much used at present, are well adapted for the utilization of waste-gases from furnaces with working-doors on the side, because in such cases, the boiler can be built directly to the rear end of the furnace—the requirement of floor-space being very small. Fig. 5 shows a

Garbe boiler with 120 sq. m. of heating-surface, attached to a reverberatory furnace, as built by the Düsseldorf-Ratinger tube-boiler works.<sup>5</sup> The boiler shown in Fig. 5 was built without a superheater; but there would be no difficulty in adding one, as, indeed, the same builders have done in other cases.

To meet the most frequent requirement, namely, that the hook of the crane must be brought as near as possible to the furnace-door, so as to facilitate the handling of the heavy ingots, it seems advisable that the outer edge of the boiler over the furnace should at least not project beyond the furnace-armature. Since, for water-tube and fire-tube boilers, the surrounding masonry occupies a large part of the available width, attention is naturally drawn to the saving of space by the use of boilers which do not need masonry. Such tubular boilers approach the locomotive, locomobile, and marine types.

In locomotive boilers, the furnace-flue enters the fire-box from below, so that the heating-gases go directly into the fire-box, and thence into the boiling-tubes. In accordance with the nature of the locomotive boiler, the gases pass through it in one direction, and escape through a sheet-metal chimney, which branches from the smoke-chamber above the firing-door. In this case, the boiler can be shut off from the furnace only when there is a second flue, leading from the main furnace-flue to a reserve chimney-flue. During the cleaning or repair of the boiler, this reserve conduit conveys the gases to a chimney, which may serve several furnaces, if necessary. But all this makes the design costly and complicated. Moreover, it must not be forgotten that the locomotive boiler, by reason of the great frictional resistance encountered by the gases in passing through the usually small heating-tubes, requires a strong chimney draft. It is therefore advisable, in order to avoid this evil, to choose heating-tubes of larger diameter, sacrificing thereby a few square meters of heating-surface.

For welding-furnaces with waste-gases of very high temperature, the locomotive type of boilers is not well adapted, since the pointed flame from the furnace strikes directly upon the tube-walls, and might easily make them leak. This type is likewise unsuitable where only a natural chimney draft is employed, because, when the furnace-doors are opened, the entrance of cold air tends to produce leakiness of the tube-ends.

Fig. 6 shows a boiler once designed by the present writer to be

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<sup>5</sup> Such boilers, each with  $2 \times 250 = 500$  sq. m. heating-surface, were built in 1912 at the "Phoenix" works, to utilize the waste-gases of Martin open-hearth furnaces. See description in later pages.

heated by furnace-gases. It is a variant of the marine boiler. A short vertical flue (usually 2 m. long) leads the gases from the furnace-flue into a corrugated tube, *b*, lying along one side in the boiler. The first 0.6 m. of this tube are lined with refractory material. The gases pass through the vertical flue *a* and the tube *b*, into a reversing chamber, *c*, in which a superheater, *d*, may be advantageously placed; and from this chamber they pass back through the boiler in the small boiling-tubes, *e*, which, like the corrugated tube, lie along one side. Finally they are received, at the end at which they entered, in a smoke-chamber, *f*, of thin sheet-metal, and are conveyed at a greatly reduced temperature through the vertical flue *g* to the subterranean chimney-flue *h*. To make all parts of the boiler accessible, the superheating coils are placed in the reversing-chamber opposite the corrugated pipe, so that when it is necessary to tighten up the smoke-pipes, or clean them from soot, they can be easily reached from both sides after the corresponding doors have been opened. The inside of the corrugated tube itself is accessible through the door *k*, which has a peep-hole, *i*.

A direct connection of the main flue, *a*, with the flues *g* and *h* is established by breaking through the thin wall *m*, separating *a* from *g*. When this is done, the furnace-gases will be drawn through *g* and *h* into the chimney, without touching the boiler at all. The introduction of valves, etc., for this purpose was avoided, because they would not have endured the high temperature which, at one point in the main flue, often melts the refractory lining. It should be added that, in later constructions of this type, the boiler rests upon a grating of beams, carried by six wrought-iron columns. Since the temperatures in the corrugated tubes are much higher than in the small tubes near it, care must of course be taken that the latter do not become loosened in the tube-walls through expansion and contraction. This consideration affects the design of the corrugated tube and the length adopted for the small tubes. Boilers of this type have been erected in considerable numbers at various works, and have run satisfactorily for several years.

Fig. 7 shows a modification of the type, in which the gases finally escape through a sheet-metal chimney over the boiler. A direct connection between furnace and chimney can be easily effected in this case, as in the preceding. It is only necessary to line both the smoke-chamber and the chimney with refractory material, and then to provide either a sliding cut-off or a removable separating wall, as shown in Fig. 6.

Experiments conducted upon a boiler about like that of Fig. 6.

through 45 days (90 shifts) of the running of the heating-furnace on small forgings, gave the following results :

|                                                                                   |                  |
|-----------------------------------------------------------------------------------|------------------|
| Grate-area of the heating-furnace.....                                            | 1.2 sq. m.       |
| Hearth-area (width, 1.3 m.).....                                                  | 4.0 sq. m.       |
| Distance from mid-hearth to beginning of fire-tubes.....                          | 6.5 m.           |
| Length of connecting flue between furnace and fire-tubes.....                     | 2.5 m.           |
| Total length of furnace.....                                                      | 6.2 m.           |
| Total width of furnace.....                                                       | 1.8 m.           |
| Heating-surface of boiler.....                                                    | 61.0 sq. m.      |
| Heating-surface of superheater in smoke-chamber.....                              | 5.6 sq. m.       |
| Proportion of furnace grate-area to boiler heating-surface.....                   | 1:51             |
| Total length of boiler.....                                                       | 5.25 m.          |
| Diameter of boiler.....                                                           | 1.7 m.           |
| Diameter of flame-tube.....                                                       | 0.7 to 0.8 m.    |
| Consumption of coal in 45 days (9 shifts).....                                    | 234 metric tons. |
| Consumption of coal per hour, about.....                                          | 217 kg.          |
| Consumption of coal per hour per sq. m. grate-surface, about.....                 | 181 kg.          |
| Consumption of coal per hour per sq. m. boiler heating-surface, about.....        | 3.56 kg.         |
| Amount of water evaporated during experiments.....                                | 594 met. tons.   |
| Amount of water evaporated per hour.....                                          | 550 kg.          |
| Amount of water evaporated per hour per sq. m. boiler heating-surface, about..... | 9.0 kg.          |
| Amount of water evaporated by 1 kg. coal.....                                     | 2.54 kg.         |
| Average steam-pressure.....                                                       | 5.7 atm.         |
| Average temperature of superheated steam.....                                     | 310° C.          |
| Superheating.....                                                                 | 148° C.          |
| Temperature of boiler feed-water, about.....                                      | 20° C.           |
| Quantity of heat transmitted to 1 kg. superheated steam, about....                | 710 h. u.        |
| Quantity of heat consumed in steam-production from combustion of 1 kg. coal.....  | 1,800 h. u.      |
| Average heating-value of coal consumed.....                                       | 5,100 h. u.      |
| Hence, proportion of heating-value utilized in making steam, about.....           | 35 per cent.     |
| Temperature of waste-gases escaping from boiler, about.....                       | 320° C.          |

In another experiment, lasting only through three shifts, an evaporation of 2.85 kg. water per kilogram of coal was reached. This would be a utilization of nearly 40 per cent. It should be observed that these experiments were made upon a boiler somewhat too small for the furnace, on which account the results are not particularly remarkable. Most of the boilers afterwards erected of this or similar type had about 80 sq. m. of boiler heating-surface, and from 10 to 12 sq. m. of heating-surface in the superheater, with which dimensions a steam-temperature of 400° C. was often attained, under favorable conditions of furnace-operation.

Among the chief advantages of this type of boiler are its small space-requirements, easy adaptation, and total freedom from masonry.

In case of a great fall in temperature but a comparatively small

quantity of heat, which would not warrant the building of a boiler, the heat of the escaping gases can be utilized, if the locality be suitable, and the need sufficient, in a superheater, placed behind or (very easily) over the furnace. The steam-temperature can then be regulated in a highly simple, though not economical, fashion, by admit-

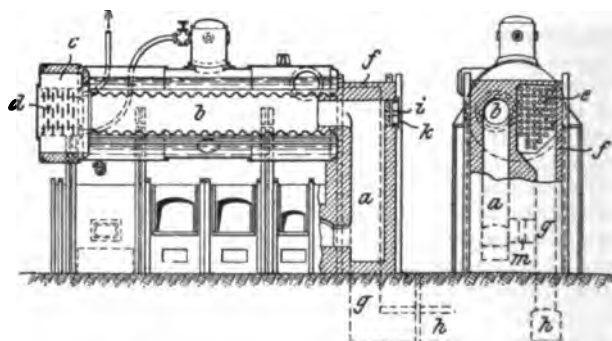


FIG. 6.

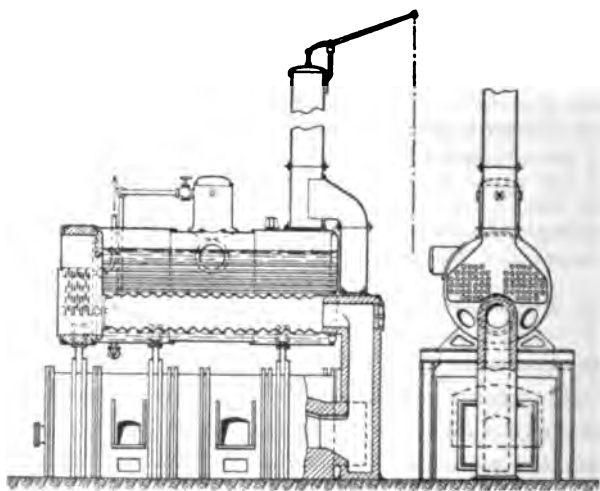


FIG. 7.

FIGS. 6 AND 7.—WASTE-HEAT BOILERS APPROACHING THE MARINE TYPE.

ting air into the superheater through two holes in the masonry. This strongly cools the hot gases, and correspondingly lowers the steam-temperature.

As a general rule, however, when the heating surface has been properly determined, such special means of regulation are not re-



quired, since the quantity rather than the temperature of the chimney-gases is likely to vary.

That, moreover, the utilization of the hot gases in preheaters may be advisable even when their temperature is considerably below  $600^{\circ}\text{C}.$ , is shown in Fig. 8, which represents such an arrangement, applied to the waste-gases from the boiler-plant, as well as from four sheet-heating furnaces. This plan works satisfactorily, and up to expectation.

An inquiry addressed to several works using hot waste-gases under boilers established the following:

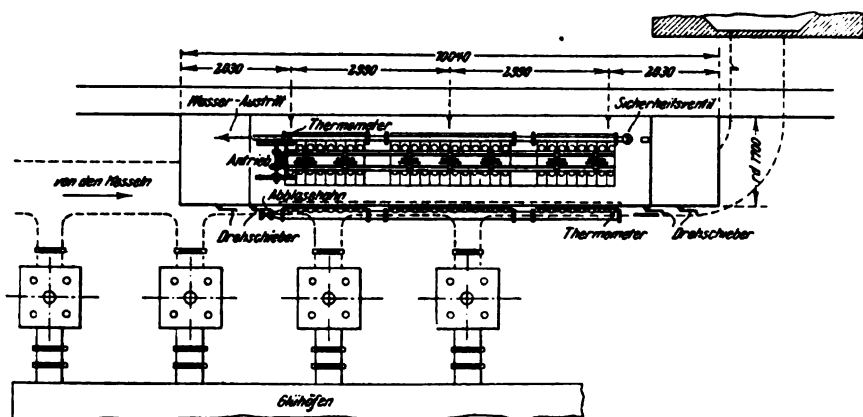


FIG. 8.—PREHEATERS CONNECTED WITH SHEET-HEATING FURNACES.

Precise tests of efficiency had been made almost nowhere, so that only partial reports of the results of practice accumulated in the course of time were available. But these reports were more valuable for the expert operator than the figures obtained by any special tests. They showed in general, that with puddling-furnaces, from 2.5 to 3.5 kg. of steam per kilogram of coal were generated under boilers having from 40 to 80 sq. m. of heating-surface—the quantity of steam produced per square millimeter per hour being from 10 to 15 kg.

With the gases from welding-furnaces, boilers having up to 130 sq. m. of heating-surface produced from 7 to 12 kg. of steam per square meter per hour, representing from 3.5 to 5.5 kg. of steam per kilogram of coal. Of course these figures are subject to great variation, according to the amount of material heated in furnace per unit of time, the nature of this material (ingot-iron or wrought-iron), and its condition (hot or cold) when charged. Upon the production of steam per square meter of heating-surface per hour, the size of the boiler also has an effect.

In the operation of heating-furnaces for hammers, and especially also in furnaces heating thin sheets, it is advisable to introduce fresh air (preferably preheated) into the gases before or in the boiler, in order to effect the combustion of still unburned gas, and thus increase the steam-production.

A similar use of the hot waste-gases from zinc-furnaces has been introduced very recently, and promises to receive a rapid extension, the results so far having been very satisfactory, indicating an increase of from 15 to 20 per cent. in the utilization of the coal. In the cement-industry, the recently adopted revolving tube-furnaces permit the use of boilers, located behind them, for this purpose. The glass-manufacture has long utilized in the same way the waste-heat of its furnaces, even installing, for the preheating of water, apparatus which employs only the radiant heat of the furnace-arch.

The foregoing discussion shows that the utilization of the hot chimney-gases from directly-fired reverberatory furnaces is in very many cases practicable, and in not a few cases highly economical.

#### IV. THE UTILIZATION OF WASTE HEAT FROM REGENERATIVE FURNACES.

This department of the subject is incomparably more important than the preceding, because the number and the size of the Siemens-Martin furnaces are so much greater than those of the heating-furnaces for rolling-mills and hammer-forges described above.

In regenerative furnaces, there is already a partial utilization of waste heat for preheating gas and air; but its principal purpose is to raise the combustion-temperature in the hearth by raising the temperature of the entering gas and air; the recovery of heat thus effected is not very great, compared with the amount which still escapes unused; and it is therefore worth while to inquire whether a saving of further heat, which would otherwise escape to the chimney, can be effected without injury to the operation of the Martin furnaces.

The quantity of heat escaping at present, for the most part without hindrance, from these furnaces is very large—about 30 per cent. of the total heat employed (according to Professor Mayer's experiments. 29 per cent.; according to Springorum, 32 per cent. These figures come from well-managed works, so that 30 per cent. as an average is not too high).

To these losses, due to the high temperature of the escaping gases, is to be added another, caused by radiation in the furnaces and chambers, which may be estimated at 40 per cent. From these figures we

may deduce approximately the economic effectiveness of such furnaces.

Pfoser in Achern has attempted to utilize in part the radiant heat of a furnace arch, as shown in Fig. 9, which represents such an arrangement for preheating water, placed over the arch of a glass-furnace. This preheater has about 10 sq. m. of heating-surface, and consists of a coil of pipe, over the furnace-arch, through which the water passes. With glass-furnaces, where this method of preheating has been considerably used, it has been found to transfer about 300 to 500 h. u. per square meter of heating-surface. This cannot be called a very great success, but it makes a beginning; and it remains to be seen whether a better way of recovering the radiant heat may not soon be attained. Meanwhile, the placing of a coil full of water on

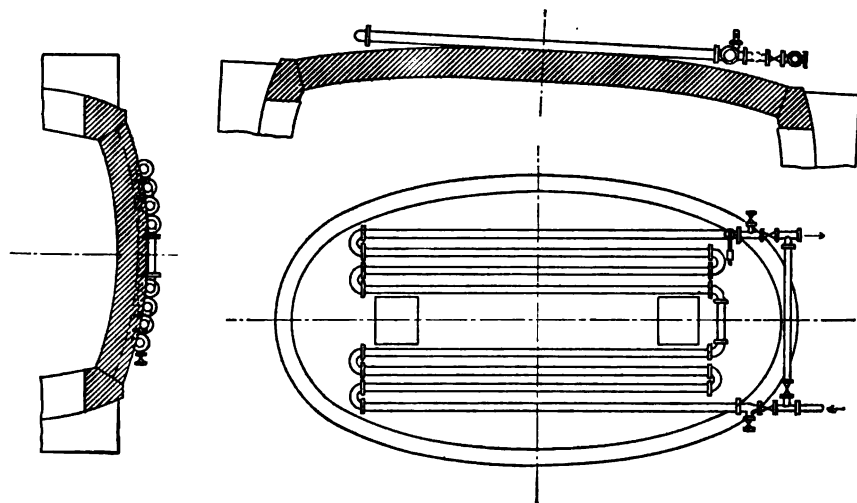


FIG. 9.—PREHEATER FOR WATER, UTILIZING THE RADIATED HEAT OF THE ARCH OF A GLASS-FURNACE.

the top of a furnace-arch is rather a ticklish business; and many a manager would not risk it. Much easier and simpler is the recovery of heat from the waste-gases, as described below.

The average temperature of the escaping gases of the open-hearth, according to numerous determinations at various works, is about  $700^{\circ}$  C., or from  $200^{\circ}$  to  $300^{\circ}$  below that of the heating-furnace gases considered in the earlier parts of this paper. Hence we have to reckon with a somewhat smaller possible recovery, inasmuch as the transfer of heat through heating-surfaces will be smaller. Yet such a recovery is not only practicable but profitable, because the quantities of gas upon which it is carried out are almost always very large.

Prof. Dr. Mayer found in his experiments upon the heat-economy

of the Martin furnace that during the production of 1,000 kg. of steel 667,000 h. u. escape in the hot waste-gases. The investigations of Mackenzie on an entirely different and differently operated furnace gave a loss of 1,000,000 h. u. In both cases the temperature of the waste gases was 700° C.

Of course it would be impossible to recover in any way the whole of this heat. After treatment, the gases would always escape at last at some temperature or other; and, moreover, every transfer of heat involves some loss.

To be perfectly safe, and to reach values which can be, with certainty, verified in practice, we shall use the somewhat unfavorable figures given by Mayer.

But first we must consider certain characteristic conditions of the Martin process itself, in order to avoid the great mistake of proposing any method which would react injuriously upon that process.

The first requirement is that for a given heating surface the boiler should be as small as practicable, in order, on one hand, to permit its installation where available space is limited, and, on the other hand, to reduce to a minimum the loss through radiation and conduction.

Furthermore, the construction and operation of the boiler should be, if possible, such that no interruption for the purpose of cleaning it will be required during the entire furnace-campaign of from 250 to 350 days. This requirement can be met by the use of pure water (surface-condenser water), and by such a construction as will permit outside cleaning of the boiler during operation.

The construction should also be such that occasional explosions, occurring when valves are reversed, will not injure the boiler. This condition is fulfilled by making the boiler-structure of a large number of single elements, with large open areas between them, so that the pressure from an explosion may pass through without doing harm. Moreover, these single elements must be able to resist occasional gas-puffs.

For this, as well as the first-named reason, boilers holding a large amount of water are out of the question.

Finally, the boiler, which is placed in the chimney-flue of the Martin furnace, must not present too great a resistance to the passage of the waste-gases. The reason for this requirement is not alone that the draft might be injured, and the chimney might prove inadequate; for the chimney does not play so very important a rôle when artificial draft is at hand. The chief reason is, that the pressure from a possible explosion should pass between the single members of the boiler-structure, without injury to the boiler.

The obvious requirements, that the boiler should not require too much attendance and maintenance; that safety of operation should be secured; and that the cost of installation should not be too great—need only be mentioned in passing.

All these requirements together can be met by a boiler, the elements of which are made of water-tubes; for, in the first place, such boilers combine large heating-surface with small bulk, and can be operated in a given case with small contents of water; secondly, the outside cleaning of such heating-surfaces is easily performed, if necessary, while the boiler is running; thirdly, the third and even the fourth requirement above stated can be satisfied by a suitable arrangement of the tubes; and fourthly and lastly, such heating-surfaces are comparatively inexpensive, and, when design and shopwork are good and solid, are highly safe against interior and exterior pressure.

In a boiler for the utilization of the hot chimney-gases of Martin furnaces in the production of steam, we distinguish the boiler proper, the superheater, and the preheater.

It is well to place the superheater before the boiler, or at least at the beginning of the draft, and the preheater behind the boiler. In calculating the necessary heating-surfaces, it seems best to begin with the preheater, then to calculate for the superheater, and to end with the calculation for the boiler. In my book, *Die Abhitzkessel*, I have given such calculations for a 30-ton Martin furnace, assuming an hourly steam-production of 2,000 kg. The several heating-surfaces were: preheater, 125 sq. m.; superheater (250° C. steam-temperature), 10 sq. m.; boiler, 200 sq. m.

But since, after utilization, the gases would be so cool that the chimney-draft could not overcome the increased resistances, it is self-evident that such utilization is practicable only when natural draft is not relied upon, but the cooled gases are moved by an exhaust-fan.

This would require in the case named a theoretical expenditure of 6.4 h-p. But in view of the comparatively low efficiency of fans of this size I have assumed for safety as required to draw off the chimney-gases, 40 h-p.—which would represent a fan-efficiency of less than 20 per cent.

The calculation of profit from such an installation, costing 36,000 marks, is as follows:

|                                                                                                                              |               |
|------------------------------------------------------------------------------------------------------------------------------|---------------|
| Average steel production per hour.....                                                                                       | 5,166 kg.     |
| Steam-production from 340 sq. m. aggregate heating-surfaces of attached boiler, in terms of steam at 10 atm. and 250° C..... | 2,000 kg.     |
| Work of fan per hour.....                                                                                                    | 40 h-p.       |
| Cost of plant, including fan.....                                                                                            | 36,000 marks. |

Assuming the works to contain six furnaces, of which five are constantly in operation, we shall have :

|                                                                           |                |
|---------------------------------------------------------------------------|----------------|
| Cost of the boiler-plant.....                                             | 216,000 marks. |
| 1. Amortization, 10 per cent., and interest, 5 per cent.....              | 32,400 marks.  |
| 2. Attendance and repairs.....                                            | 7,600 marks.   |
| 3. Cost of power, $5 \times 40 = 200$ h-p. at 4 pfennige for 1 kw-hr..... | 50,000 marks.  |
| Total annual costs .....                                                  | 90,000 marks.  |

Since in the five units 10,000 kg. of steam are produced hourly, or 240,000 kg. daily, or, in round numbers, 77,000 metric tons per annum, the cost of this steam is about 1.20 marks per 1,000 kg.

If we now consider the work done with this steam through a steam-turbine, we find that at the rate (including all losses) of 7 kg. of steam per kilowatt-hour, the 10,000 kg. produced hourly will generate about 1,400 kw-hr., of which (150 kw-hr. being deducted for the driving of fans, etc.) 1,250 kw-hr. per hour, or 30,000 per day, or say 9,000,000 per year, remain available, at a cost of 40,000 marks for steam-generation and 40,000 for the turbine-plant, or 80,000 marks total annual cost. In other words this electrical energy is obtained for less than 1 pfennig per kilowatt-hour.

*No other way of producing electrical energy can show a lower cost.* Even water-power, favorably located and unfailing in adequate supply, is seldom so cheap, if the amortization of the plant be provided for at about the rate assumed in the foregoing example.

It must be noted also, that the generation of electric energy in the works—that is, in the place where it is to be used—is independent of the season or weather. A given production of steel gives a corresponding, and (apart from minute variations) almost uniform quantity of energy in this form.

It is praiseworthy to try to make use of the water-powers of which so many are still neglected; but the *falls of temperature* which occur before our eyes deserve our attention likewise, since they are easier to appropriate, possess more constant strength, do not need long lines of transmission, and can therefore be made available at smaller expense of installation. Moreover, the utilization of these great temperature-falls in large steel-works recovers enormous quantities of heat, otherwise wasted.

Further results of calculation are graphically shown in Fig. 10.

Thus far, only the theoretical determination of the heating-surface areas and the probable costs and profits have been considered. The

records of actual practice with waste-heat boilers attached to Martin furnaces are likewise interesting.

In the Duisburg steel-works of the Phoenix Co., five such boilers were erected last year behind Martin furnaces, and put in operation; and thorough tests were made under the direction of the Imperial

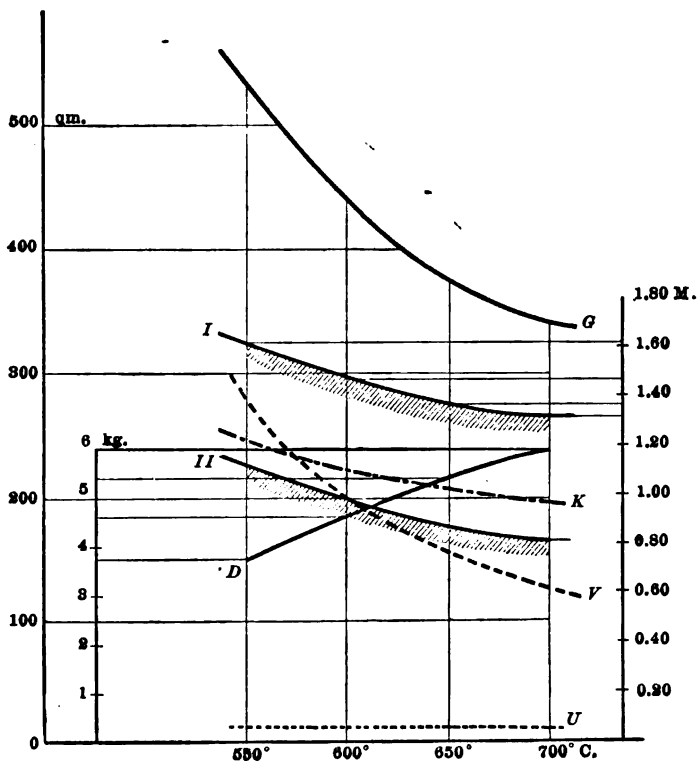


FIG. 10.—DIAGRAM SHOWING HEATING-SURFACE AND COST (INCLUDING INTEREST AND AMORTIZATION) OF PRODUCING 1000 KG. OF STEAM AT 10 ATM. AND 250° C, FOR VARIOUS TEMPERATURES OF THE ENTERING GAS AND AN ASSUMED GAS-PRODUCTION OF 2000 KG. PER HOUR.

- $P$  = Necessary Preheating Surface in sq. m.
- $K$  = Necessary Boiler Heating Surface in sq. m.
- $U$  = Necessary Superheating Surface in sq. m.
- ////  $I$  = Cost of 1000 kg. steam, with an electric power price of 4 pfennig per kw-hr.
- ////  $II$  = Cost of 1000 kg. steam, when the electric power driving the fans is furnished by the plant itself. This curve shows therefore the steam-cost proper.
- $D$  = Steam-production per sq. m. of total heating-surface.

German Steel Works. From the report of these tests by Chief Engineer J. Schreiber, which was published this year in *Stahl und Eisen*, I present here only the average figures of a series of experiments, last-

ing through 20 shifts, upon a boiler erected behind a 50-ton furnace (No. 4).

|                                                                  |                  |
|------------------------------------------------------------------|------------------|
| Average temperature of boiler feed-water, about.....             | 20° C.           |
| Average temperature of gases entering boiler, about.....         | 700° C.          |
| Average temperature of gases leaving boiler, about.....          | 350° C.          |
| Temperature-fall of gases in boiler, about.....                  | 350° C.          |
| Average steam-pressure in boiler.....                            | 7.5 atm.         |
| Consumption of current in operating fan per hour.....            | 57 kw.           |
| Product of steel during experiment.....                          | 2,000 met. tons. |
| Product of steel per hour.....                                   | 8.3 met. tons.   |
| Coal consumption per ton of steel made.....                      | 234 kg.          |
| Evaporation per sq. m. heating-surface (without preheating)..... | 7 kg.            |
| Steam-production per ton of coal.....                            | 1,842 kg.        |
| Steel-production per ton of coal.....                            | 449 kg.          |
| Heating-surface of boiler.....                                   | 500 sq. m.       |

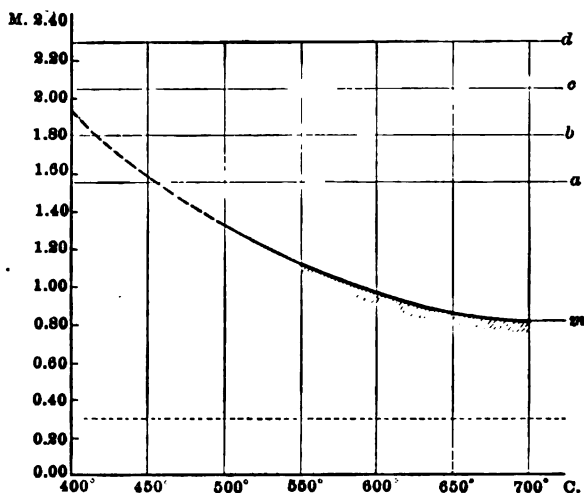


FIG. 11.

The great economy of such a utilization of waste heat appears very clearly from this statement, especially if it be considered that, even in this first undertaking of the kind, not the least injurious effect of the boiler upon the operation of the furnace was noticeable.

Finally, Fig. 11 exhibits graphically a comparison between the cost of 100 kg. of steam produced directly by coal combustion and the corresponding cost of production by means of the waste heat in Martin furnace-gases. In this diagram, the horizontal lines give the cost of 100 kg. of steam from direct combustion, according to the varying prices of coal, while the curve shows the cost of the same quantity of steam produced from waste-gases of different temperatures, as shown along the bottom line. The dotted horizontal line



next above shows the approximate proportion of the total cost required in the use of directly-heated boilers to cover interest, amortization, and labor. The costs are given on the left, in marks and decimals, the interval being 0.20 mark.

The intersections of the horizontal lines by the curve mark the limit of economy in utilizing the waste-gases. It will be seen that this limit is extended in proportion as the temperature of the waste-gases or the price of coal is increased.



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Feb. 1, 1914.

## Grain Growth in Silicon Steel.

BY W. E. RUDER, SCHENECTADY, N. Y.

(New York Meeting, October, 1913.)

It has been pointed out by Stead<sup>1</sup> that grains of considerable coarseness may be developed in steels containing from 3 to 5 per cent. of silicon, and in a previous paper<sup>2</sup> the present author has shown that under the proper conditions of annealing single grains having an area of 50 sq. cm. may be obtained.

It is the purpose of this paper to discuss in more detail the conditions promoting the growth of these grains, in the hope that the experiments described may throw some additional light upon the general problem of grain growth in metals.

These silicon steels lend themselves particularly well to such experiments because of the ease with which the change in structure may be followed and because of the fact that the effect of the carbon present is largely obliterated by the high percentage of silicon. This forms a solid solution with the iron, which acts very much like a pure metal. This alloy has been found to have but one critical point, viz.,  $Ar_2$ . This point, determined by Roberts-Austen for Hadfield's 4 per cent. Si alloy, was found to lie at 703° C. Vigouroux<sup>3</sup>, in working with pure Fe-Si alloys, finds this point to rise from 750° C. for 0.5 per cent. Si to 860° for 6 per cent. alloy, with a flat region in the curve from 3 to 4 per cent. Si. No accurate determination of this point has been undertaken by the present author, but it has been roughly determined to lie between 730° and 750°.

In the preliminary experiments, some of which have been described in a previous paper, it was found that practically all of these steels, when annealed to 1,200° C. or higher, showed grains of comparatively large size. These grains varied in size, however, from about 4 sq. mm. to 50 sq. cm. (see Figs. 1 and 2) under the same conditions of anneal, and it was for the purpose of determining the cause of this difference in size that the experiments herein described were undertaken.

From a preliminary study of the chemical composition of the specimens

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<sup>1</sup> *Metallographist*, vol. i, No. 4, pp. 289, 325 (Oct., 1898).

<sup>2</sup> *Journal of Industrial and Engineering Chemistry*, vol. v, No. 6, pp. 452 to 458 (June, 1913).

<sup>3</sup> *Comptes rendus*, vol. clvi, pp. 1374 to 1376 (1913).



FIG. 1.—PORTION OF A SINGLE GRAIN OF SILICON STEEL OBTAINED BY ANNEALING TO  $1,300^{\circ}\text{C}$ . IN VACUUM. ACTUAL SIZE.



FIG. 2.—SILICON STEEL ANNEALED AT  $1,300^{\circ}\text{C}$ . IN VACUUM AND ETCHED WITH CONCENTRATED  $\text{HNO}_3$ .

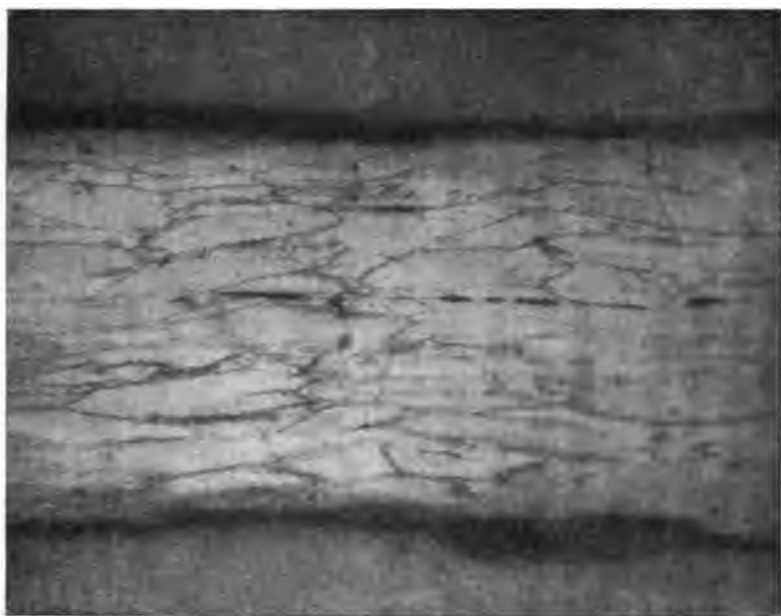


FIG. 3.—SILICON STEEL, UNANNEALED, ETCHED WITH DILUTE  $\text{HNO}_3$ .  
90 diameters.

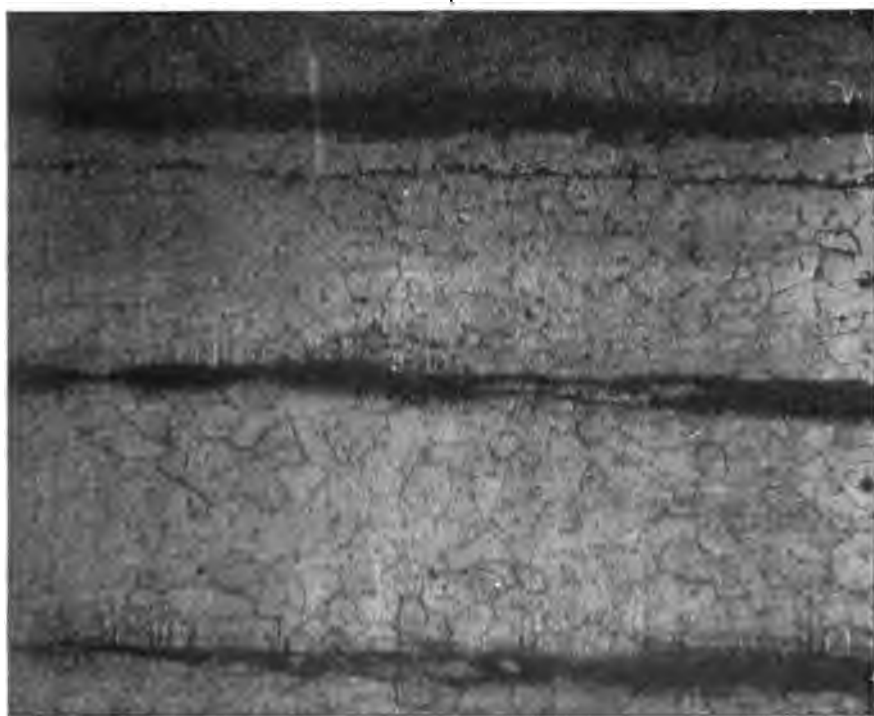


FIG. 4.—SILICON STEEL ANNEALED AT  $800^\circ\text{C}$ . AND ETCHED WITH  $\text{HNO}_3$ .  
90 diameters.

it was found that the carbon (which varied from 0.01 to 0.06) had apparently no effect whatever upon the grain size. Those specimens containing about 3.25 per cent. Si had the largest grains, but these were of very irregular shape. Specimens containing 3.75 per cent. or more had grains of very regular shape, so called "equi-axed," and varying in size from 4 sq. mm. to 3 sq. cm. It so happened that the 3.25 per cent. specimen ran a little higher in manganese and phosphorus than the others, and it may be that this has some influence in forming the large grains, but this has not been determined. In fact, no effort has yet been made to determine the exact influence of the silicon content or of any of the impurities. The 3.25 per cent. alloy was used in all of the following experiments, so that the question of composition may be set aside for the time being.

The complete analysis is here given: C, 0.05; Mn, 0.15; P, 0.038; S, 0.026; Si, 3.24 per cent.

### *The Influence of Annealing.*

For most of the work no special polishing was required—simply smoothing up with No. 0 emery, after removing the scale, and etching with  $\text{HNO}_3$ . A rapid etching was obtained by using concentrated  $\text{HNO}_3$  and alternately dipping and washing the samples, allowing them to remain in the acid only a fraction of a second at a time.

All of the annealing experiments were carried out in tube furnaces, in a stream of pure dry hydrogen, to prevent oxidation, and the time given represents the time at temperature, not including heating and cooling.

As received from the mill, the material has the well-known fibrous structure shown in Fig. 3 (90 diameters).

Upon annealing to  $800^\circ \text{C}$ . in a closed pot, the real grains are formed, but are still of microscopic dimensions (see Fig. 4). In order to determine the temperature at which the larger grains begin to form, that is, such as can be readily discerned by the unaided eye, eight samples, varying in thickness from 0.005 to 0.025 in., were annealed in hydrogen for 3 hr. at  $850^\circ \text{C}$ ., cooled over night, and then polished and etched with concentrated nitric acid. There was no change in structure. This was repeated at  $920^\circ$ ,  $960^\circ$ ,  $1,000^\circ$ ,  $1,050^\circ$ , and  $1,100^\circ \text{C}$ . Samples more than 0.007 in. thick began to show slight grain growth at  $1,050^\circ \text{C}$ ., while the 0.025-in. sample showed quite large sized grains (see Fig. 5). Above this temperature the large grains did not show any visible change, but the smaller grains grew until the entire remaining field was occupied by large equi-axed grains. These grains, once formed, could not be changed by any heat treatment short of actual fusion.



1,050° C. 4 Hr.



1,000° C. 8 Hr.



915° C. 7 Hr.



850° C. 2 Hr.



1,400° C. 2 Hr.



1,300° C. 8 Hr.



1,300° C. 8 Hr.



1,230° C. 13 Hr.

FIG. 5.—SILICON STEEL, ANNEALED, ETCHED WITH CONCENTRATED NITRIC ACID.

In order to determine the influence of time of anneal upon the grain growth, several 0.025-in. sheets were placed in a platinum-wound furnace and heated in hydrogen to  $915^{\circ}\text{C.}$  for 17 hr.,  $1,000^{\circ}\text{C.}$  for 8 hr., and  $1,230^{\circ}\text{C.}$  for 15 hr. After each period one sample was removed and examined, while the others remained in the hot furnace. No change what-

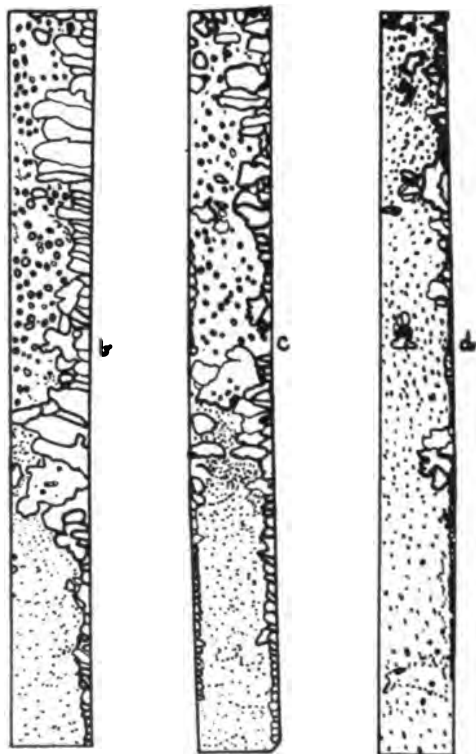


FIG. 6.—SHOWING THE GROWTH OF GRAINS ALONG THE DIRECTION OF STRAIN.  
 ‡ Size.

ever occurred until after the last period. Here the grains were quite large, but still of the same order of magnitude as those heated to an equal temperature for 2 hr.

At the lower limit of grain growth, *i.e.*,  $1,050^{\circ}\text{C.}$ , it required about 15 min. to obtain any noticeable gain in size, but at  $1,300^{\circ}\text{C.}$  a few grains of from 3 to 5 mm. diameter formed in 3 sec. Upon further heating these sometimes grew to from 8 to 10 mm., but, as a rule, continued heating produced other grains, so that in 15 min. the whole sheet would be covered with grains of about 5 mm. average diameter. The grains grow slowly at  $1,050^{\circ}$  and reach their maximum size in about 3 hr., or less if the tem-



perature is higher. This maximum size is determined by the condition of strain existing in the sheet or bar, as will be explained later.

Another series of samples previously run showed quite large grains after annealing at  $950^{\circ}\text{C}$ . (see Fig. 6, reduced to five-eighths size). In these samples the grains begin at the edges and grow inward and are of the kind described by Dr. Percy as columnar. That these grains started to grow from one edge only of two of the strips and from both edges of the third, is explained by the fact that samples *b* and *d* were cut from either side of *c*, and the grains have grown only in those regions strained by cutting, and have their longest dimension in the direction of the strain.



FIG. 7.—SECTION OF SILICON STEEL INGOT SHOWING GROWTH OF GRAIN IN THE DIRECTION OF THE RADIAL STRAINS CAUSED BY COOLING.

Similar columnar or radial grains were found in the cast metal (see Fig. 7), where radial strains had been set up on cooling.

#### *The Influence of Mechanical Working.*

In previous work it had been noticed that no matter how high the temperature of anneal was carried, short of the actual melting point, the grains always formed with their longest dimension in the direction in which the original sheet had been rolled. This is quite remarkable in that the large grains do not grow under  $1,050^{\circ}\text{C}$ ., and it is difficult to understand how any strain could persist after the piece had been annealed to  $800^{\circ}\text{C}$ . Repeated experiments, however, have demonstrated beyond question that the effect of rolling does persist, very much like the latent image on a photographic plate. This fact, coupled with the facts noted in the preceding paragraph, gave rise to a closer investigation of the effect of mechanical working.

The two samples shown in Fig. 8 were rolled along the edges *a*, so that the samples were reduced in thickness for only about one-third of the width. After annealing at 1,050° C. for an hour they developed the structure shown. The deformed areas have small grains, while those

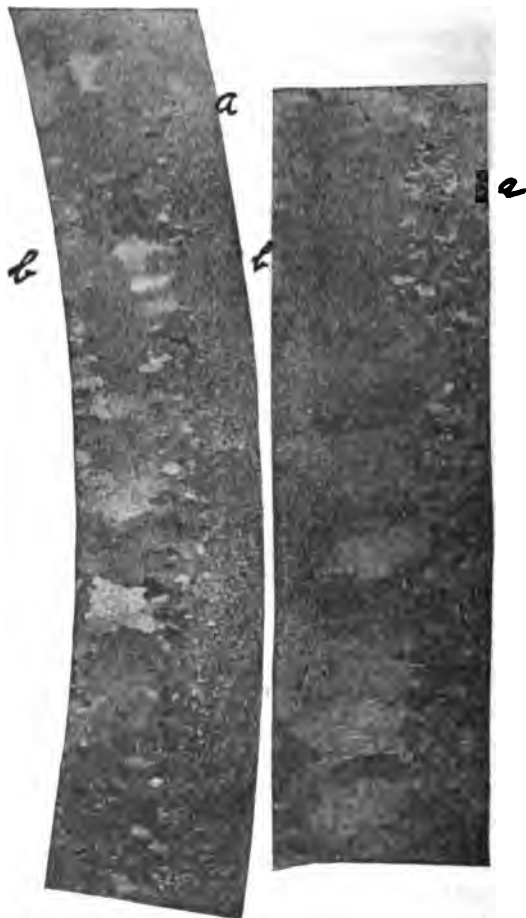


FIG. 8.—SHOWING THE EFFECT OF STRAIN UPON THE STRUCTURE OF SILICON STEEL. SAMPLES WERE ROLLED ALONG THE EDGES *a*. ACTUAL SIZE.

areas which were put under strain without any actual deformation developed grains of considerable coarseness, which have grown in the direction of strain. Samples hammered with a ball hammer showed the same effect, *i.e.*, a small fine-grained circular area surrounded by a fringe of large grains extending into the surrounding unaltered portion.

Several large-grained samples were then hammered lightly in different portions of the grains, and these worked areas, after annealing above  $900^{\circ}\text{C}$ ., were found to be broken up into smaller grains. In this case,



Fig. 9



Fig. 10

FIGS. 9 AND 10.—LARGE-GRAINED SAMPLES IN WHICH SMALL GRAINS WERE FORMED BY HAMMERING ALONG THE BOUNDARIES OF THE ORIGINAL GRAINS, AND SUBSEQUENTLY ANNEALING. ACTUAL SIZE.

however, only the deformed areas were altered, while the original grain otherwise remained unchanged.

Figs. 9 and 10 show how these smaller grains may be formed at will wherever desired.

From these facts it is evident that there must be some critical strain at which the grains grow to the largest dimensions. Such a condition of strain in the metal would explain why sometimes in the same sheet



01



02



03



06



02



01

First Setting of Rolls.

10

9

Second Setting.



11



12



13



15



12



11

16

FIG. 11.—SHOWN IN INCREASE OF GRAIN SIZE WITH DECREASE OF ROLLING PRESSURE.

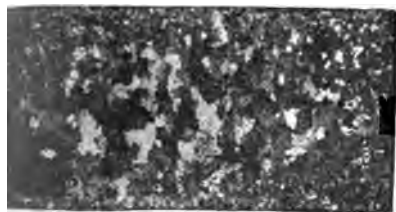


22



21

Fourth Setting.



20



19

Third Setting.



18



26



25



24



23

Fourth Setting.

FIG. 12.—SHOWING INCREASE OF GRAIN SIZE WITH DECREASE OF ROLLING PRESSURE.

extremely large grains are found surrounded by very fine ones when conditions of heat treatment were precisely the same throughout the sheet.

In order to determine, as far as possible, how to obtain those conditions of strain most favorable to grain growth, a series of 26 samples were rolled under different conditions of temperature and rolling pressure. The first eight samples were rolled at from  $600^{\circ}$  to  $1,000^{\circ}$  C. with one setting of the rolls. The pressure was then decreased and another set run, and so on throughout the series. After this treatment, the samples were all annealed to  $950^{\circ}$  C. for 3 hr., etched and examined.

Figs. 11 and 12 show how the grain size increases with decreased rolling pressure. The pronounced effect of strain is a little more clearly illustrated in Fig. 13, where the middle area only has been subjected to the mechanical working. This was accomplished by placing a narrow strip of metal on the center so that only the area covered by this strip would be touched by the rolls. No. 1 was given a very light pass and remains practically unaltered; Nos. 2 and 6 were given heavy passes through the center section; Nos. 3 and 4 were rolled under moderate pressure and Nos. 7 and 8 under light pressure. The growth of grain under heavy pressure is seen to be outside the deformed area, while under very light working the deformation was not sufficient to produce any strain outside of the actual area under pressure, and so only those grains grew as in No. 7. An intermediate condition is that of No. 4, where the growth has extended outside of the area of deformation, but very little.

F. Robin<sup>4</sup> obtains practically the same results with steel and other metals, for temperatures below  $900^{\circ}$  C. Hammering, rolling, or compression tends to develop a coarsely granular structure *outside* of the deformed area. The granules in the deformed area mutually limit each other and are small, while just outside of the area their development is greater and extends into the unaltered section. As has been shown in the case of silicon steel, he finds that punching, shearing, or bending produces, on reannealing, large granules, which extend as far as from 7 to 12 mm. into the unaltered region.

That conditions of strain may be set up during annealing is shown in Fig. 14, which is one of six samples so placed in a furnace that the lower end was held at  $1,340^{\circ}$  C., while the upper end was at about  $900^{\circ}$  C. These were examined after 1, 1.5, 2, and 4 hr. The large grains grew in all samples in the region between the  $900^{\circ}$  area and the  $1,300^{\circ}$  area and began as a small grain on one edge of the sheet and grew across. Only one of the sheets in the final stage is shown in the illustration. This growth was evidently due to the strains set up by the difference in expan-

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<sup>4</sup> *Comptes rendus*, vol. clv, pp. 716 to 719 (1912).

sion between the hot and cold areas and not to a flow of heat, as might at first be supposed.

The temperature at which the grain begins to grow to visible size in a sheet free from unequal strains has been shown to be  $1,050^{\circ}\text{C}$ . A slight strain, such as is caused by a light blow from a hammer, reduces the temperature necessary to about  $725^{\circ}\text{C}$ ., as nearly as could be determined. At this temperature a slight growth was noted after 0.5 hr.

It is well known that ordinary mild steel or wrought iron coarsens rapidly between  $600^{\circ}$  and  $750^{\circ}\text{C}$ .,<sup>5</sup> and when heated above  $A_1$  becomes fine again, and that quenching from any intermediate temperature gives a fine-grained structure. In silicon steels the conditions for coarsening are quite different and this difference is undoubtedly due to the effect of the silicon upon the carbon, thus causing the Si-Fe alloy to act more like a pure metal. If this assumption is correct we would expect no fining of the grain above  $A_1$  in very pure iron, and such indeed has been found by Stead and Carpenter<sup>6</sup> to be the case. Silicon steel differs from the pure iron of Stead and Carpenter in that its grains are formed on heating, and quenching from the highest temperatures does not refine the structure. This would go to show that there is no difference between the structure of the gamma and the alpha iron in the presence of silicon.

The large grains, if subjected to mechanical working, require a higher temperature ( $1,020^{\circ}\text{C}$ .) to produce a recrystallization than do the small grains under strain ( $750^{\circ}\text{C}$ .). If unstrained, however, the small grains begin to grow at the same temperature at which the strained large grains are recrystallized. The large grains are then more stable under strain than are the small ones.

### *Summary.*

It has been shown

1. That the grain of a 3.25 per cent. silicon steel may be considerably coarsened by annealing at temperatures above  $1,050^{\circ}\text{C}$ . If the sheets are subjected to any kind of unequal strain the very large grains begin to form at about  $725^{\circ}\text{C}$ .

2. That the grains form on heating at a rate depending upon the temperature; i.e., the higher the temperature above  $1,050^{\circ}\text{C}$ . the quicker the grains form.

3. That the grain size is predetermined by the amount and kind of mechanical working to which the sheets have been subjected and not by the rate of heating or cooling.

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<sup>5</sup> Stead: *Journal of the Iron and Steel Institute*, vol. liii (1898, I), pp. 145 to 186.

<sup>6</sup> *Journal of the Iron and Steel Institute*, Sept., 1913.



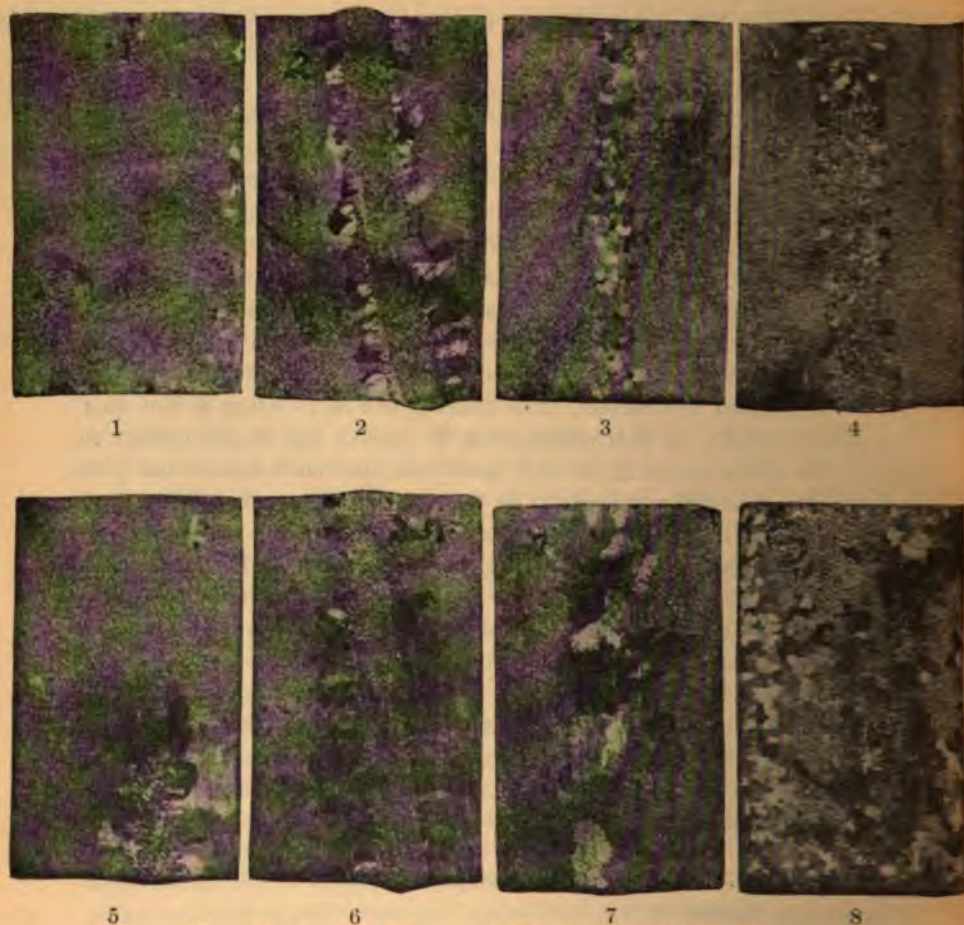


FIG. 13.—SHOWING EFFECT OF PRESSURE ON GRAIN SIZE.



FIG. 14.—SHOWING EFFECT ON GRAIN SIZE OF STRAIN SET UP DURING ANNEALING.



4. That light working or straining produces large grains, and heavy working produces fine grains.
5. That the large grains once formed cannot be altered by any heat treatment short of actual fusion.
6. That only very slight growth is obtained in sheets less than 0.007 in. thick.
7. That the only way this coarse grain structure may be broken up is by mechanical working followed by a reanneal above 1,020° C.
8. That the effect of cold mechanical working persists after heating to incipient fusion.

#### DISCUSSION.

JOHN G. HOMAN,\* Follansbee, W. Va.:—I would like to make a few remarks about Mr. Ruder's paper, in connection with the grain growth, particularly of silicon steel. Dr. Benedicks, I believe, has found that most of the elements located in the uneven series of the periodic system are those which produce grain growth or large grain field; while the others, the even series, are the refiners. Inasmuch as last year there was made in America something over 120,000 tons of steel used in the electrical industries, and inasmuch as 100,000 tons of that steel was silicon steel, the paper is of particular interest, because of the fact that there seems to be a definite connection between large grains and magnetic quality in steel, and I think that if Mr. Ruder's paper should point out to us a way in which we can increase the grain growth of silicon steel in our mills, it will be of enormous practical value. One particular thing, however, that seems to be summarized in the paper, is the fact that it requires something over 1,200°, or in the neighborhood of a thousand, I may say, to produce these phenomena, and that does not seem to be practical just at present in our systems of closed heating.

P. H. GRIFFIN, New York, N. Y.:—Does the gentleman mean the recrystallization of the metal?

JOHN G. HOMAN:—There certainly must be a recrystallization of the metal.

P. H. GRIFFIN:—Well, I should say that in cast iron, which is the only thing with which I have any experience, it is a very simple thing to alter the crystallizing of metal by subjecting it to the variation of heat and cold.

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\* Non-member.

JOHN G. HOMAN:—The attempt to produce the grain growth has been by different systems of heating and subjecting the mass to pressure or alteration of mass.

ALLERTON S. CUSHMAN,\* Washington, D. C.:—I would like to know whether Mr. Ruder would be willing to state whether any investigations were made with respect to the magnetic and electric constants of the specimens after their grain growth had been modified by these experiments.

W. E. RUDER:—In answer to the question, I would say that the total watt loss is apparently not affected by size of grain; that is, on an average. Occasionally we find that the watt losses may be higher or lower, but we cannot ascribe that directly to the size of grain. On the other hand the hysteresis loss of the large grain is considerably lower than of the fine-grained structure; but the eddy current loss is almost double. The material has decidedly different magnetic qualities.

ALLERTON S. CUSHMAN:—The point I wanted to get at was whether in the case of very extraordinary sized grains a maximum efficiency was developed.

W. E. RUDER:—No. The experiments which I made upon hysteresis were confined to one series. You can realize the difficulty of getting a definite test on hysteresis and getting materials sufficiently uniform so that one could say the grains were all of the same size. The large-grain material would vary from a quarter of a square inch up to a square inch in size, so no definite conclusion can be arrived at there; but by taking an average lot of small, medium, and large grains the hysteresis follows the grain size very sharply. I might say that the eddy-current loss, too, is dependent upon the grain size up to the point where the grain size equals the thickness of the sheet; and beyond that there is apparently no difference.

ALLERTON S. CUSHMAN:—The idea I was trying to express has been in my mind for some time. I think it is not at all improbable that the same consideration comes into play with respect to magnetic and electric qualities as has been discussed here in an earlier paper with respect to the relation of strength of material with the growth of the grain, and the cementitious material, or material that lies in between grains. I asked the question in pursuing the idea whether there is not some ideal size of grain that gives the very best results.

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\* Non-member.

W. E. RUDER:—That I have not been able to determine very exactly. I cannot get the grains to grow large and small and get them where I want them. They do not always grow a quarter of an inch or half an inch as I would like them. As a matter of fact, the magnetic qualities of a sheet are very nicely brought out by placing some of this large-grain material in a magnetic field and getting an image of the flux by scattering on iron filings. In that case the crystals are very definitely outlined by the iron filings. This investigation was carried out in connection with a previous paper in which I had discussed the intergranular cement in silicon steel. There it showed either an intensified magnetism at that point or a gap.

HENRY M. HOWE, New York, N. Y.:—In Figs. 15 and 16 I condense some of the late remarkable discoveries as to this extraordinary grain-coarsening, as distinguished from the normal slow coarsening which occurs on long and high heating. The abscissæ represent grain size, the ordinates temperature, continuous lines rising temperature, and broken lines falling temperature, somewhat after Brinell. Plastically deformed impure iron, Fig. 15 (wrought iron and low-carbon steel cold rolled), coarsens with rising temperature, from say 450° to 850°, to refine abruptly on passing Ac<sub>3</sub>, without further coarsening on further heating. Pure iron, Fig. 16, does not coarsen thus in heating but does coarsen abruptly on cooling past Ar<sub>3</sub>.<sup>7</sup>

Strikingly unlike as these conditions look at first, on closer examination the coarsening seems in essence the same, the congenital coarsening of non-gamma iron crystals. I say non-gamma in order to avoid the contentious question as to the existence of beta iron.

To explain, Sauveur has shown<sup>8</sup> that the coarsening of Fig. 15 occurs only after a certain critical degree of plastic deformation. According to our present ideas, the essence of that deformation is the amorphizing of part of the alpha iron. The amorphous iron recrystallizes on reheating, or to be more specific dis-amorphizes, passing not from one crystalline form to another but from the amorphous to the crystalline state, which is quite a different thing. It is apparently during the birth of this crystalline iron that this enormous coarsening

<sup>7</sup> Stead and Carpenter: Crystallising Properties of Electro-deposited Iron, *Journal of the Iron and Steel Institute*, Sept., 1913. I found that even electrolytic iron coarsened somewhat if the temperature rose high enough, e. g., to 1,300°

<sup>8</sup> Note on the Crystalline Growth of Ferrite, *International Association for Testing Materials*, VI Congress, 1912, II, 6.

The doubling of the curve above A<sub>3</sub> is only to indicate that this part of the curve represents both heating up and cooling down, and not to suggest that the grain size changes, when rising temperature gives place to falling. Let the reader make abstraction of this doubling, and mentally superpose the unbroken on the broken line.

occurs, hence I call it the congenital coarsening of non-gamma iron crystals.

The refining of this impure iron on rising above  $Ac_3$  is not surprising, meaning either that the crystals of gamma iron do not inherit the size of the non-gamma iron whence they spring, or that the crystals of the non-gamma iron born on again cooling past  $Ar_3$  do not. But as Goerens<sup>9</sup> has shown that the effects of overstrain are removed chiefly between  $500^\circ$  and  $520^\circ$ , and as therefore this should be the temperature of dis-amorphizing, more precise experiments are needed

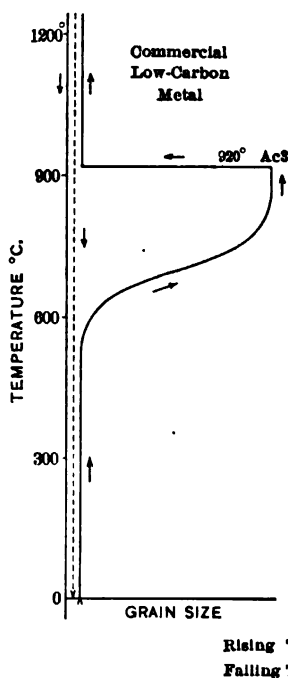


Fig. 15.

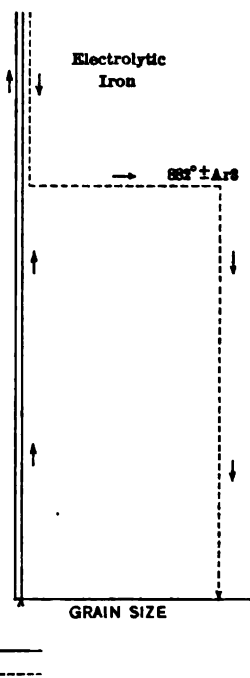


Fig. 16.

FIGS. 15 AND 16.—BEHAVIOR OF VERY LOW-CARBON METAL.

The commercial coarsens on dis-amorphizing and refines at  $Ac_3$ , the electrolytic coarsens at  $Ar_3$ .

to show whether this coarsening will occur there. It was actually observed by Professor Sauveur at  $650^\circ$ , though Stead<sup>10</sup> reported that it occurs between  $500^\circ$  and  $770^\circ$ .

Turning to the pure electrolytic iron, Fig. 16, its coarsening occurs very abruptly in the change at  $Ar_3$  from gamma to non-gamma iron, so that this too is congenital coarsening of non-gamma iron.

<sup>9</sup> Iron and Steel Institute, *Carnegie Memoirs*, vol. iii, p. 383, Fig. 42 (1911).

<sup>10</sup> The Crystalline Structure of Iron and Steel; *Journal of the Iron and Steel Institute*, vol. liii (No. I, 1898), pp. 145 to 189. Brittleness Produced in Soft Steel by Annealing; *idem*, vol. liv (No. II, 1898), pp. 137 to 154.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Feb. 1, 1914.

## The Slagging Gas Producer.

BY WILLIAM HUTTON BLAUVELT, SYRACUSE, N. Y.

(New York Meeting, October, 1913.)

THE type of gas producer in which the ashes are fluxed and run off as slag was among the very earliest made. Ebelen built the first one in 1840 at Audincourt, France, only a year after the installation of the first gas producer of which we have record. Charcoal was used as the fuel, with blast-furnace slag and clay as flux. My interest in this type of producer began when as a boy I saw the fluxing producer at Chester, N. J., which was invented by W. J. Taylor, and described by him in 1881.<sup>1</sup> This producer was invented independently by Mr. Taylor to meet the difficulties he experienced in making producer gas for roasting sulphurous iron ores. It will be of interest to review briefly his description of his producer. It was built like a small blast furnace, having a hearth 24 in. in diameter and 24 in. high. The bosh angle was 25° from the vertical; the diameter at the bosh 4 ft. and at the top 3 ft.; the total height 12 ft. The producer contained one water-cooled tuyere 12 in. above the bottom, with a 1.5-in. nozzle. Depth of the coal above the tuyere, 6 ft. Mr. Taylor mixed the coal with from 30 to 40 per cent. of basic blast-furnace slag to flux the ash. Occasionally some limestone was also used, but never limestone alone, as the use of the furnace cinder gave a larger volume of slag and made it easier to maintain a proper fluidity. The producer was blown with a small Weimer blowing engine, delivering 300 ft. of air per minute, at from 1 to 1.5 lb. pressure. The slag was tapped every 2 hr. and was black and glassy in appearance. Broken or egg size anthracite was used. The fine sizes of anthracite could not be made to work. Mr. Taylor expressed the belief that bituminous coal could be used if not too fine, but no experiments were made with this coal. Runs were made of four weeks' duration, with no stops or changes. Mr. Taylor reported the following advantages:

1. Excellent gas, very uniform in quality. The high fuel bed permitted no air to pass unconsumed, and the gas was almost entirely free from carbonic acid.

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<sup>1</sup> *Trans.*, ix, 309 (1880-81).

2. No cleaning of the producer to remove ashes, so no waste of coal and no cessation or irregularities in the flow of gas.

3. Quantity of gas easily controlled, and "anyone familiar with blast-furnace practice can run it, particularly if cinder for fluxing is available."

The power required for blowing the producer for gasifying 200 lb. of coal per hour was 1.5 h.p., or, assuming 3 lb. of coal per horse power, 2.25 per cent. of the coal gasified. This consumption of steam compares favorably with ordinary producers, but the rate of gasification, about 16 lb. per square foot per hour, was not remarkable for the size of fuel used. Mr. Taylor did not continue the operation of the fluxing producer, mainly on account of the skilled attention required in its operation. A man "familiar with blast-furnace practice" is often not available for the operation of producers. The high pressure of blast used and the necessity for employing a blowing engine were also among the disadvantages. He did not state why only the larger and more costly sizes of anthracite could be used, but at present comparative prices this would be a serious objection.

There appears to be no further record of experiments with the slagging producer until within the last few years. A battery of "S. F. H." slagging producers was installed at the glass works at Gironcourt in 1907, and this plant is reported to be still in operation, furnishing gas to the glass works. In the report of the operation of this plant there is no reference to the type of flux used, but it is reported that all kinds of fuel are successfully gasified, no matter what the content of ash, the only necessity being that the fuel contain sufficient fixed carbon to develop heat to gasify the carbon and fuse the ash. It is claimed that the heat required to fuse the ash is much less than the equivalent of the carbon lost in the ash of ordinary producers. One coal containing from 20 to 25 per cent. of ash gave a gas containing from 2 to 3 per cent. of  $\text{CO}_2$ , 28 to 30 per cent. of  $\text{CO}$ , and 9 to 10 per cent. of  $\text{H}_2$  and  $\text{CH}_4$ .

The most recent work done with the slagging producer is that described by the Bureau of Mines.<sup>2</sup> This work was done at the Pittsburgh Laboratory of the Bureau, with a view to determining the value of this type of producers for utilizing low-grade fuels. It does not appear from the report of these tests that the slagging producer gives results essentially superior to other types of producers for gasifying low-grade fuels. The experiments at the Coal Testing Plant of the Bureau at St. Louis in 1903 and 1904, showed that fuels containing very high percentages of ash could be successfully gasified in producers of the ordinary type.

The report of the Bureau of Mines does not give the dimensions of the

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<sup>2</sup> The Slagging Type of Gas Producer, *Technical Paper No. 20*, U. S. Bureau of Mines (1912).

producer used, but six air tuyeres were employed, and in addition four separate steam tuyeres located above. On account of the extremely high temperatures, it was found necessary to provide pipe coils in the brick lining for water cooling, and magnesite brick was used between the coils and the fire. The cooling coil extended over a space 20 in. above the air tuyeres. The blast pressure used was from 5 to 16 in. of water, and it was found advantageous to pre-heat the air to about 440° F. Steam was employed at times up to 0.75 lb. per pound of fuel gasified, and it was found that this produced no chilling effect on the slag, as the steam was introduced above the point of highest temperature. It was found difficult to operate this type of producer intermittently without trouble from the chilling of the slag, so it does not appear that it would be satisfactory in cases where gas is required only in the daytime, for example. The analysis of the gas showed high CO and low CO<sub>2</sub> content, the latter being as low as 1.5 per cent., but no analyses are reported showing the effect of steam on the composition of the gas.

The experiments developed a number of difficulties in the fluxing of the ash, and it was found that the theoretical percentage of limestone was not nearly sufficient to produce a fluid slag. Frequently large quantities of fine ash blew over with the gas, "because of the heavy air blast," and probably some of the limestone was blown over with it. One occasion is reported where practically all of the ash and limestone escaped in this way. Comparing the air pressures reported with those used in producers of the ordinary type, it would be interesting to observe, in further experimenting, if a careful proportioning of the depth of the fuel bed to the rate of combustion would reduce the trouble from this source.

When the conditions were right and the operation of the producer was maintained continuously there was no trouble in tapping off the slag in a satisfactorily fluid condition, and in maintaining a uniformly high quality of gas. The Bureau has been carrying on experimental work since the publication of the above report, and we hope to have before long the results of this additional work.

The latest work with the slagging producer is described in a French patent issued to E. Servais, Jan. 21, 1913. In this producer there are two sets of tuyeres, one set arranged just above the fire zone and supplied with steam or gas to reduce the temperature in the fuel bed by its decomposition. A second set of tuyeres is arranged just below, through which the air blast is admitted. These tuyeres are set in an eccentric ring, in order that a whirling movement may be given to the air in order to agitate the molten slag in the crucible. The inventor claims that this rapidly melts down any solid lumps that may form. A combustion chamber is arranged beneath the crucible in which a mixture of gas and air may be burned to help in maintaining the temperature above the fusing point of the slag.

In operating this producer the fuel is sprayed with lime water, or mixed with a suitable amount of basic blast-furnace slag.

The work done thus far with the slagging producer does not indicate that the problem has been thoroughly worked out, and there is much experimenting to be done before this producer can be put on a commercial basis. The increasing cost of the higher grades of fuel, and the large amounts of low-grade fuel that are available in almost all parts of the country, made the perfecting of a producer that will successfully gasify these low grades a most interesting and important problem.

There is one field where the slagging producer would have material advantages. It would be ideal for gasifying coals having a fusible ash. No matter how badly the ash might clinker in an ordinary producer, it would have no terrors for the slagging producer; in fact, the more fusible the ash, the better. Such coals are ordinarily gasified with the use of an excess of steam, which is not only costly to generate, but injurious to the gas, as much of it passes through undecomposed. There are many of these clinkering coals which are objectionable in the ordinary gas producer, and if the slagging gas producer can be worked out so that the cost of operation is about on a par with other types, it will find a field of usefulness waiting for it.

In connection with the treatment of clinkering coals I give below a brief bibliography of publications on clinkering, for which I am indebted to F. N. Morton of Philadelphia.

Calculation of Clinker in Blast Furnaces by the Platz Method.—*Le Genie Civil*, Apr. 9, 1904.

Management of Water Gas Generators. By Dr. John F. Wing.—*American Gas Light Journal*, Apr. 18, 1910, p. 730; Apr. 25, 1910, p. 772.

Best Anthracite Coal for Use in Water Gas Generators.—*Progressive Age*, July 1, 1910, p. 547.

What Causes Clinker and What is its Chemical Composition?—Question Box, Ohio Gas Light Association, 1905, p. 252.

Relation Between the Composition of Coal Ash and Its Fusibility. By Eugene Prost.—*Moniteur Industriel*, Dec. 11, 1897. (A translation of this article appeared in the *Colliery Guardian*, Mar. 18, 1898.)

Prost's *Manual of Chemical Analysis*.

The Freezing Point of Iron. By H. C. H. Carpenter.—*Journal of the Iron and Steel Institute*, 1908, III, p. 290.

Clinkers and the Fusing Temperature of Coal Ash.—*Coal Trade Journal*, June 29, 1910.

Clinkering of Coal. Results of Tests for Effect of Various Constituents in the Ash. By Lionel S. Marks.—*Engineering News*, Dec. 8, 1910, p. 623.



Steam for Preventing Clinkers.—*Power*, Feb. 7, 1911, p. 240.

The Relation Between Composition and Fusibility of Coal Ash. Report of Investigation.—*Colliery Guardian*, Oct. 1, 1897.

A Study of the Fusibility of the Ashes of Combustibles. By H. Le Chatelier and Chantepie.—*Bulletin Société d'Encouragement*, Feb., 1902.

*Bulletin No. 325, U. S. Geological Survey*, p. 28.

The Operation of the Boiler Plant and the Cost of Making Steam. By J. T. Sparrow.—*Proceedings of Association of Edison Illuminating Companies*, 1908, p. 192.

\*The Temperatures at Which Certain Ferrous and Calcic Silicates are Formed in Fusion, and the Effect upon these Temperatures of the Presence of Certain Metallic Oxides. By H. O. Hofman.—*Transactions of the American Institute of Mining Engineers*, 1899, vol. 29, p. 682.

The Fusing Temperature of Coal Ash.—*Power*, Nov. 28, 1911, p. 802.

Fusion Temperature Coal Ash.—*Bulletin 5, Fuel Testing Co.*

\*NOTE: In this article the following references are given:

Lampadius.—*Journal des Mines*, 1809, 18, p. 171; also, *Handbook der Allgemeinen Hüttenkunde*, 1801–1810, 1, p. 127. H. Dieterich, Göttingen.

Sefström.—*Jernkontorets Annaler*, 1828, 1, p. 155; also, Erdmann's *Journal für Technische und Oekonomische Chemie*, 1831, 10, p. 145.

Berthier.—*Traité des Essais*, Paris, 1834, 1, p. 430.

Percy-Smith.—Percy, *Fuel*, London, 1875, p. 59.

Bischof.—*Dingler's Polytechnisches Journal*, 1862, 165, p. 378.

Plattner.—Merbach, *Die Anwendung der Erwarmten Gebläseluft in der Metallurgie*, Leipsic, 1840, p. 288.

Åkerman.—*Jernkontorets Annaler*, 1886, p. 1; also, *Stahl und Eisen*, 1886, pp. 281, 387; "Graphical Representation," by Howe, *Transactions of the American Institute of Mining Engineers*, 28, p. 346.

Howe.—*Transactions of the American Institute of Mining Engineers*, 18, p. 724.

Gredt.—*Stahl und Eisen*, 1889, 9, p. 759; also, Åkerman's Critique, *id.*, 1890, p. 424.

## DISCUSSION.

JOSEPH W. RICHARDS, South Bethlehem, Pa.:—There are two striking advantages of the slagging gas producer: one is that you can use a coal with a very fusible ash, and are not bothered by the clinkering of the coal; but the particular advantage is that on a very small floor space or ground space you get a very high capacity. Where room or space is at a premium, then, the slagging producer can give you a large output on a small area. There is one necessary loss, however, that I wish to call attention to: namely, that in a slagging gas producer you necessarily lose all the heat of the slag which comes out of the furnace, so that the heat efficiency of the furnace as a gas producer is diminished by the sensible heat of the slag coming out, whereas in the ordinary gas producer the ashes come out nearly cold and you save nearly all their sensible heat.

DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 89th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Feb. 1, 1914.

## The Briquetting of Flue Dust in the United States by the Schumacher Process.

BY FELIX A. VOGEL AND A. M. TWEEDY,<sup>1</sup> NEW YORK, N. Y.

(New York Meeting, October, 1913.)

SINCE the publication of Prof. J. W. Richards's paper on The Schumacher Briquetting Process,<sup>2</sup> this process has been in operation on a practical scale in two plants in the United States, and a few notes on the results obtained may be of interest.

An experimental plant, consisting of a toggle press and a hydraulic press, was installed at Johnstown, Pa., together with the necessary bins and other equipment, and an attempt was made to briquette a mixture of Mahoning fines and blast-furnace flue dust, in a ratio of 7 parts of ore to 3 parts of dust. The results were unsatisfactory, in that the briquettes made were not hard enough to stand the severe handling to which they were subjected in the various transferences necessary between the press and the furnace. The trouble was due to several causes: First, the mechanical arrangement of the plant, which did not lend itself to a proper hardening and loading of the briquettes into the cars. Second, the irregular composition of the flue dust, as to both its lime and its fine coke contents. Third, the variability of the moisture content of the ore, and its viscosity when wet. Fourth, the ratio of fine ore to flue dust; that is, it was attempted to bind in too large a quantity of fine ore for the small amount of flue dust used. The first trouble could be overcome, and has been improved upon in the plant as it stands to-day. The second trouble was important, because of the small amount of dust used as a binder, and might have been easily removed by mixing the flue dust of the different furnaces, which, however, was never done. The third difficulty was more serious, but could have been partly solved, had it been possible to meet this along with the fourth difficulty, by decreasing the percentage of ore in the briquettes. It was proposed to do this, but it seems that the problem at the works in question is, primarily, to prepare Mahoning fines for reduction in the blast furnace, and only secondarily to use up the flue dust, and a solution along this line did not seem to be interesting.

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<sup>1</sup> Non-member.

<sup>2</sup> *Trans.*, xliii, 387 (1912).

In Lackawanna, N. Y., a single-press experimental plant, Fig. 1, was installed in October, 1912, and operated for a trial period until Aug. 1, 1913, when it was taken over by the steel company, and is now being operated by them. The plant, Fig. 1, consists of a single toggle press installed at the end of the regular coke bins, two of which bins have been utilized as storage bins for flue dust. The flue dust, as drawn in hopper-bottom cars from the dust catchers of any one of the seven furnaces, is dumped through a 1-in. wire screen into the dust storage bins. Any coarse coke or limestone caught in the screening is shoveled or raked into an adjoining coke bin. From the storage bins the dust is drawn off through cylindrical spouts, 18 in. in diameter, to two table proportioners feeding a standard pug mill 10 ft. long, of the ordinary single-screw type. In this pug mill, or mixer, water and a 10 per cent. solution of iron sulphate are added, the amount of solution being such that the actual salt added is 0.25 per cent., by weight, of the flue dust. The amount of water is varied with the character of the dust, and is such that, with the water in solution, the total moisture in the dust as it leaves the mixer is from 8 to 10 per cent. From the mixer the dust feeds directly into the press, where rectangular briquettes 7.75 by 6 by 3.25 in., are formed, under a pressure of 5,600 lb. per square inch. It would be out of place to go into a detailed description of the press, more than to say that it is a self-contained toggle press of the revolving-table type, with 12 molding boxes, and designed to turn out from 18 to 22 briquettes per minute. The pressure plunger is counterbalanced by a counter-pressure plunger in an oil cylinder, under a pressure of 135 atmospheres of compressed nitrogen, which has a dual purpose, in that it insures a uniform pressure on each briquette, besides protecting the press in case of foreign material getting into the molding boxes. Further features are safety shearing pins on the table-drive mechanism, which disengage the table from the main driving shaft in case the revolution of the table is stopped in any way. The press, with ordinary care as to lubrication and adjustment, gives no trouble.

The press is operated at a speed to deliver 20 briquettes per minute, or 1,200 per hour. Briquettes weigh from 11.5 to 12 lb. apiece, so production is at the rate of about 6 tons per hour. The briquettes are discharged automatically from the press table on to a belt conveyor by a "kicker." Sufficient storage space was not provided in the briquette shed for all briquettes made running both day and night turns, so the day-turn briquettes are run on the conveyor directly to flat-bottom gondola cars, where they are taken off by hand and stacked. On the night turn, briquettes are taken off the conveyor by hand and stacked in the shed, where they are allowed to stand about 24 hr., then thrown by hand or loaded by the conveyor again into hopper-bottom cars. Both of these arrangements are very crude and expensive, but of the two, the method of

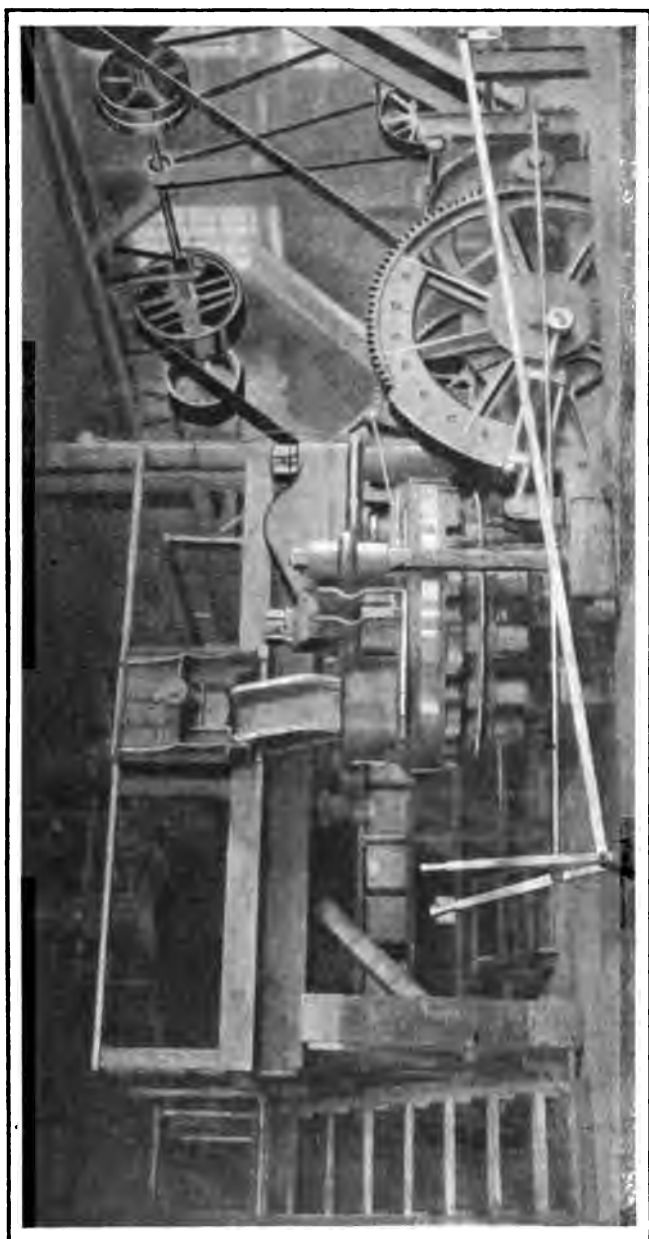


FIG 1.—EXPERIMENTAL PLANT AT LACKAWANNA.

stacking the briquettes on the ground proves the more satisfactory, as the briquettes have proper time and ventilation to harden as they should, which is not the case in the cars, where the briquettes are packed too tightly and get very little ventilation.

It was found that very hot dust—that is, dust directly from the catchers—did not make good briquettes; the explanation being that the moisture in the briquettes was driven off before time was given for any cementing reaction to take place. As brought out in previous discussions on the subject, moisture is a necessary factor in the cementing action. The dust should certainly be cool enough not to burn the hand when handled before going into the press. In cases where the briquettes were too hot, and dried too fast, some improvement could be made by sprinkling the briquettes with water. This helped to harden the briquettes to the depth to which the moisture penetrated, but as this was not very deep, the briquettes at best were only “case hardened.” In a number of cases, particularly when the furnaces were acting badly, or when a shipment of lime contained a large amount of fines, the flue dust was found to contain a large percentage of unslaked lime. Slaking was started in the mixer, especially if the dust was hot, and was not completed until after the briquettes were molded and set to harden, when the incidental expansion of the lime in slaking tended to loosen and crack the briquettes. This difficulty was met by introducing steam into the mixer, and by changing the lead of the blades of the mixer screw so that the dust was held in the steamy mixer until the lime had time to thoroughly slake, when it did no harm to the briquettes.

Experiments were made with different percentages, and with different catalytic solutions, notably  $\text{CaCl}_2$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{HNO}_3$ ,  $\text{FeSO}_4$ , and pickling liquor from a nearby galvanizing plant.  $\text{CaCl}_2$  and  $\text{FeSO}_4$  and pickling liquor, all gave good results, and it was found most practical to use commercial  $\text{FeSO}_4$  in the percentage above mentioned. Pickling liquor would have been cheaper, but arrangements could not be made to obtain it in the quantity desired.

Liners for the molding boxes had to be changed every six weeks, and experiments were made with different steels and temperings, to determine the best material for such liners. Ordinary open-hearth rail steel with 0.80 per cent. of carbon, untempered, proved the best. Liners now being made are tapered on diagonally opposite sides, so as to be reversible when one side is worn, and yet to make good briquettes until entirely worn out. Untapered box liners, when worn even a very small amount, tend to cause lamination and cracks throughout the briquettes, the reason being that the wearing takes place most where the briquette is formed, some 3 in. from the top, or throat, of the box, and the briquette, in being discharged through the narrower throat, has to be squeezed, and so cracked.

Practical operations at Lackawanna were on fresh flue dust, that is, dust produced currently from the furnaces, seldom more than a week old, and sometimes so fresh from the dust catcher as to be actually red hot. Experiments were made using mixtures of fresh dust and weathered dust from the stock piles, and it was found that equally good briquettes, if not better ones, are made with 50 per cent. of fresh dust and 50 per cent. of weathered dust, the reason being that the weathered dust is always cool, so that the mixture is cooler than the fresh dust alone, and the cementing reaction takes place more slowly and thoroughly. Dust some two months out of the furnace made very good briquettes, and we are led to believe that at least two or three months of weathering is necessary before dust becomes too inert for briquetting alone.

In a single month of which we have complete records, which is typical of average work, the results of operation show a production of 2,727 tons made during 23 working days, or an average production of 119 tons per day, at a total cost, including all overhead expense, of 60c. per ton. Of this cost, the largest single item, that of handling briquettes after they are made, would be cut in half, if not further reduced, in any permanent, properly designed plant. The cost of catalytic also would have been reduced if pickling liquor had been used, and the total cost might easily have been brought down to 40c. per ton.

All briquettes made during the test run were used currently on the furnaces, and accounted for themselves in tons of pig iron, without bad effects on the furnaces or on their operation. Furnace losses in flue dust, or in any other way, were not greater than they had been when the furnace carried no briquettes. Small percentages of briquettes were used irregularly on a 500-ton furnace throughout the winter and spring, and to get more conclusive results during the summer, briquettes were used on two 300-ton furnaces, where the effect of the small quantity of briquettes would be noted more readily than on the larger furnace.

A summary of operations on one furnace showed that in June, when 13.71 per cent. of briquettes was carried—the largest percentage of briquettes that had been carried for an entire month—the furnace actually made a little more iron with a smaller coke consumption and less flue dust, 2.26 per cent., than it did in previous months with less briquettes.

When the briquettes were badly broken and used in a large amount, say 25 per cent., on a single furnace, a tendency to tighten was noticed in the furnace. Whether this is due to the physical character of the charge, or to the swelling of the ores, or to excessive carbon deposition from the Mesabi ores, or to some other reason, has not been determined. That it is not serious, and can easily be overcome with a little more experience, is obvious from European practice, where the process is in operation in more than 20 different plants, in a number of which even a larger percentage

of briquettes is used on a charge, with no tightening tendencies, and decidedly beneficial results in furnace operation.

In conclusion, and referring again to the previous papers on the subject and their discussions, it may be said that nothing new has developed as regards the action of the catalytic agent in the cementing action of flue dust, when subjected to pressure. This cementing action is partly due to the formation of a silicate of lime and alumina, similar to the action taking place in the setting of Portland cement, and partly due to the oxidation and hydration of the different oxides of iron to  $\text{Fe}(\text{OH})_2$ . Whatever the action of the catalytic may be, it has certainly been shown that such a catalytic is necessary in order that the cementing action may take place.

Very little direct evidence was secured as to what happened to the coke in the flue dust. It went into the furnace with one result, or a combination of several results. It might have been thrown out again as increased flue dust, if the briquettes immediately disintegrated with heat. This, however, did not happen, as all evidence, in the fact that the briquettes accounted for themselves in tons of pig iron produced without increased losses in any way, is directly to the contrary. Then the carbon either must have combined with the  $\text{CO}_2$ , producing  $\text{CO}$  and thus enriching the furnace gases: or it was carried down with the rest of the burden and did its part in the reduction of iron. Probably both these actions take place, but, because of the comparatively small amount of briquettes used for a relatively short time, the records of results obtained were not conclusive. There are so many important and variable features in the operation of a blast furnace that test runs to prove small differences should necessarily cover a longer period than has yet been given in this case.

The adaptability of the process to American conditions has been entirely demonstrated, and we feel that, when thoroughly studied, its cheapness and simplicity, as well as the advantages of its product, will give it as general use in blast-furnace practice in this country as it now has in Europe.



DISCUSSION OF THIS PAPER IS INVITED. It should preferably be presented in person at a meeting of the Institute. If this is impossible, then discussion in writing may be sent to the Editor, American Institute of Mining Engineers, 29 West 39th Street, New York, N. Y. Unless special arrangement is made, the discussion of this paper will close Feb. 1, 1914.

## Agglomeration of Flue Dust by the Chloride of Magnesium Method at the Works of the Société John Cockerill, Seraing, Belgium.

BY EMILE HIERTZ,\* SERAING, BELGIUM.

(New York Meeting, October, 1913.)

THE first press was installed in June, 1910, and the second in March, 1911.

They produce 1,000 briquettes per hour, weighing 5 kg. (11.05 lb.) each, under a pressure of about 400 kg. per square centimeter (5,689.2 lb. per square inch).

The chloride of magnesium is received from the potash mines at Hanover in tank cars in approximately a 35 per cent. solution.

The quantity of solution added to the flue dust varies between 2 and 3 per cent., so that the briquettes contain about 1 per cent of  $MgCl_2$ . To fresh dust as much as 10 per cent. of coke breeze may be added and briquettes made that still have a crushing strength of from 25 to 30 kg. (377 to 426.6 lb. per square inch) after 36 hr., and 45 kg. (639.9 lb. per square inch) after six days.

After having treated 140,000 tons of the material, the reports of the blast furnaces show that the briquettes improved the action of a furnace and produced less dust than did Minette ore. As much as 35 per cent. of briquettes is added to the furnace charge without bad effects on operations.

The presence of chlorine did not produce any corrosion in the furnace, downtakes or other piping.

The presence of a certain amount of chlorine in the dust reduces the amount of chloride of magnesium which it is necessary to add for briquetting.

The daily production at present, with three presses, averages 200 tons.

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\* Non-member.



**Proceedings of the One Hundred and Sixth Meeting,  
New York, N. Y., October, 1913.**

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The opening session was held on Thursday morning, Oct. 16, 1913, at the Institute Headquarters in the Engineering Societies Building, 29 West 39th Street, New York, N. Y., and was called to order by President Rand, who addressed the meeting briefly before presenting Albert Sauveur, who responded to the President's address, and presided at the meeting.

The following papers were then presented in oral abstract by their authors or authors' representatives:

The Cleaning of Blast-Furnace Gas, by W. A. Forbes. Discussed by S. K. Varnes, H. N. Diehl, F. H. Wagner, Joseph Hartshorne, S. B. Marshall, J. W. Richards, J. E. Johnson, Jr., W. A. Forbes, and others.

The Generation of Steam by Waste Heat from Furnaces, by F. Peter (Leoben, Austria).

Note on the Utilization of the Waste Heat of Regenerative Furnaces, by George C. Stone.

These two papers were discussed jointly by D. S. Jacobus, E. B. Carter, T. T. Read, J. W. Richards, J. Hartshorne, and G. C. Stone.

Over-Oxidation of Steel, by W. R. Shimer and F. O. Kichline. Discussed by Allerton S. Cushman, J. E. Johnson, Jr., H. D. Hibbard, H. M. Howe, P. H. Griffin, A. Sauveur, and J. W. Richards.

The Slagging Gas Producer, by W. H. Blauvelt, was presented by title and discussed by J. W. Richards orally.

The second session was called to order at 2 p.m, with Joseph W. Richards acting as Chairman.

The following papers were presented in oral abstract by their authors, or authors' representatives:

The Use of Powdered Coal as Fuel, by Richard K. Meade. Discussed by W. R. Webster, E. W. Parker, A. Stansfield, D. S. Jacobus, P. H. Griffin, J. W. Richards, H. A. Prosser, Bradley Stoughton, W. R. Shimer, and R. K. Meade.

The Use of Pulverized Coal as a Fuel for Metallurgical Furnaces, by H. R. Barnhurst. Discussed by W. A. Evans, J. W. Richards, H. A. Prosser, T. T. Read, P. H. Griffin, A. Stansfield, K. Nibecker, and H. R. Barnhurst.

The Use of Powdered Coal as Fuel, by E. W. Shinn. Discussed by R. W. Hunt, H. A. Prosser, R. Amberg, C. C. Carter, J. G. Homan, J. E. Johnson, Jr., A. A. Stevenson, W. A. Evans, J. W. Richards, S. K. Varnes, H. R. Barnhurst, R. K. Meade, E. W. Parker, W. R. Dunn, P. H. Griffin, and E. W. Shinn.

The Scoria Process for the Manufacture of Fine-Ore Briquettes, Flue-Dust Briquettes, and Slag Brick for Building Purposes, by E. Stütz.

The Briquetting of Flue Dust in the United States by the Schumacher Process, by F. A. Vogel.

These two papers were discussed jointly by H. O. Hofman, J. W. Richards, F. A. Vogel, and E. Stütz.

The Use of Nodulized Ore in the Blast Furnace, by R. H. Lee. Discussed by J. E. Johnson, Jr., H. M. Howe, and J. W. Richards.

Agglomeration of Flue Dust by the Chloride of Magnesium Method at the Works of the Société John Cockerill, Seraing, Belgium, by Emile Hiertz.

The third session was called to order on the morning of Friday, Oct. 17, 1913, at 10 a.m. Albert Sauveur was Chairman.

The following papers were presented in oral abstract by their authors, or authors' representatives:

Determination of the Position of  $Ae_3$  in Carbon-Iron Alloys, by H. M. Howe and A. G. Levy.

Thermal and Microscopical Examination of Professor Howe's Standard Commercial Steels, by G. K. Burgess, J. J. Crowe, and H. S. Rawdon.

Discussion of the Existing Data as to the Position of  $Ae_3$ , by H. M. Howe.

These three papers were discussed jointly by Alfred Stansfield, G. K. Burgess, K. W. Zimmerschied, R. H. Sweetser, Albert Sauveur, H. LeChatelier, and H. M. Howe.

The Critical Ranges A2 and A3 of Pure Iron, by G. K. Burgess and J. J. Crowe. Discussed by H. M. Howe, Alfred Stansfield, A. A. Stevenson, Bradley Stoughton, Albert Sauveur, P. H. Griffin, R. W. Hunt, and G. K. Burgess.

The following papers were presented by title:

Ae1, The Equilibrium Temperature of A1 in Carbon Steel, by H. M. Howe.

A Chart for Use in Connection with Wet and Dry Bulb Thermometers in Making Psychrometric Determinations, by C. P. Linville.

The Future of the Chilled Car Wheel, by P. H. Griffin.

The fourth and last session was called to order by R. W. Raymond at 2 p.m. on Friday afternoon, Oct. 17, 1913.

The following papers were presented in oral abstract by their authors, or authors' representatives:

The Influence of Various Elements on the Absorption of Carbon by Steel, by R. R. Abbott. Discussed by J. A. Mathews, Albert Sauveur, and M. A. Ammon.

Shock Tests of Cast Steel, by J. H. Hall. Discussed by H. M. Howe, W. C. Chancellor, W. R. Webster, Leonard Waldo, J. E. Johnson, Jr., Bradley Stoughton, and William Campbell.

The Influence of Copper upon the Physical Properties of Steel, by G. H. Clevenger. Discussed by D. A. Lyon, A. S. Cushman, and R. W. Hunt.

The Life of Crucible Steel Furnaces, by J. H. Hall.

Grain Growth in Silicon Steel, by W. E. Ruder. Discussed by H. O. Hofman, P. H. Griffin, A. S. Cushman, H. M. Howe, and W. E. Ruder.

The following paper was presented by title:

New Design of Regenerators for Open-Hearth Furnaces, by H. F. Miller, Jr.

Robert W. Hunt then presented a resolution urging upon the proper national government committees the supreme importance of proper financial and other support to the Bureau of Standards and also requesting allied kindred American scientific and commercial organizations to act in this matter.

The meeting closed with an informal dinner at the Engineers' Club, at which Mr. Rand presided. Informal toasts were responded to impromptu by about 20 of the persons present. The attendance at the meeting was 151 members and 40 guests.



## The Position of $Ae_3$ in Carbon-Iron Alloys.

Discussion of the papers of Messrs. Howe and Levy, Burgess, Crowe and Rawdon, and H. M. Howe, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 78, June, 1913, pp. 1075 to 1136.

ALFRED STANSFIELD, Montreal, Canada:—In Professor Howe's paper on the position of  $Ae_3$ , he shows its industrial importance in determining the temperature to which steel should be heated for "grain refining." Several years ago I carried out a research on the "burning" of steel and found that while hypo-eutectoid steel should be heated to  $Ae_3$ , hyper-eutectoid steel that has been very much overheated must be reheated to the curve  $Sa$  on the carbon-iron diagram, in order to redissolve the pro-eutectoid cementite and thus to obtain recrystallization and grain-refining. This treatment was necessarily only partly successful, and I should like to ask whether the conditions of heat treatment for refining overheated high-carbon steels have been ascertained.

Speaking of the "Persistence of Solidificational Segregation" Professor Howe quotes an experiment made by Mr. Stead in which a bar of 1.2 per cent. carbon steel was immersed in a large mass of molten blast-furnace slag and allowed to cool with it. The steel was heated above the solidus (curve  $Aa$  on the carbon-iron diagram), but below the liquidus (curve  $AB$ ). A drop of eutectic carbon-iron alloy, rich in carbon, had liquated out and hung below the bar. This agrees exactly with my own observations on the burning of steel, but my interpretation differs somewhat from that of Professor Howe. Professor Howe considers that the fusion of a part of the metal (rich in carbon) shows that the solidificational irregularities of composition had persisted through the rolling and heat treatment of the steel, as otherwise no part of the steel would have been sufficiently fusible to melt. It does not appear to me that such an explanation is necessary. A piece of steel represented in temperature and composition by any point within the area  $ABa$  will ultimately resolve itself into a solid phase and a liquid phase in equilibrium with each other. It may appear that if the steel were absolutely uniform no fusion could take place, but the smallest nucleus of high-carbon, fusible alloy would ultimately bring about this separation into liquid and solid phases, by diffusion of the carbon from the solid to the liquid areas. A nucleus sufficient for the purpose might be provided by an area of pro-eutectoid cementite which had not become diffused during the

heating of the steel, and it is open to question whether even this nucleus would be necessary to produce the ultimate separation into solid and liquid phases.

The liquid phase, if 1.2 per cent. carbon steel were just above its solidus temperature, would contain about 2.5 per cent. of carbon, instead of the 3 per cent. observed by Mr. Stead. When steel is "burnt" (heated above its solidus temperature) the liquid phase forms between the grains of steel and may ultimately flow downward into the lower part of the piece of steel. Such a segregate, during slow cooling, would become still richer in carbon by deposition of crystals of austenite, and could thus easily reach 3 per cent. or more of carbon.

In § 29, "The Influence of Manganese," discussing the effect of manganese on the carbon content of the eutectoid, Professor Howe argues, Fig. 10, that a lowering of the carbon content of the eutectoid by the addition of manganese would probably steepen the lines  $GO$  and  $OS$ , and as no steepening has been observed, he infers that the carbon content of the eutectoid is not lowered. Without discussing the general question whether the eutectoid content is or is not lowered by manganese, I would like to point out that such a lowering might take place without any steepening of the curves  $GOS$ .

Let us suppose that the curves  $GO$  and  $OS$  remain of the same steepness, but that the points  $G$ ,  $O$ , and  $S$  are all lowered by the addition of manganese; then if these points are all lowered equally the carbon content of the points  $O$  and  $S$  will remain as before, but if  $MO$  is lowered less than  $G$  the distance  $MO$  will decrease, and further, if  $PS$  is lowered less than  $MO$  the distance  $(PS-MO)$  will decrease; the carbon content of the eutectoid being lowered by the sum of these changes. It is clear then that the carbon content of the eutectoid, when manganese is added, depends on the relative lowering of the points,  $Ae_1$ ,  $Ae_2$ , and  $Ae_3$ , and not merely on the steepness of the curves  $GO$  and  $OS$ .

HENRY M. HOWE:—We made a few determinations of the line  $SE$ , but I am not prepared to draw that line to-day. It is not at all of the industrial importance of the line  $A_3$ , first because but a small proportion of our steels are hyper-eutectoid, and second because refining these by heating to  $SE$  is not usually wise. In common practice we allow free ferrite to accumulate in networks in hypo-eutectoid steel, and its re-absorption by heating to  $A_3$  is not accompanied by any special difficulties. But in the case of hyper-eutectoid steel the matters are very different. Free cementite is not usually and should not be allowed to form a coarse network, because the destruction of



that network is troublesome. If you do destroy it by reheating to *SE*, it will re-form if your cooling is slow. If you cool rapidly to prevent re-forming, you may easily crack the steel. Therefore unless the conditions are such that the cooling from *SE* can be accompanied by forging to prevent the formation of a cementite network, this method of refining is unwise. It is better to agglomerate any free cementite into rounded and relatively harmless masses by holding at slightly below *A1*, than to attempt to refine by heating to *SE*.

G. K. BURGESS, Washington, D. C.:—The particular item of interest, it seems to me, is that the thermal study and the micrographic study of these specimens give practically the same results, within the limits of observation. This is extremely encouraging and shows that for this kind of work, which often is very delicate, we can work with a considerable amount of confidence by one or the other method, and obtain within reasonable limits the same results. I do not know that I have anything of importance to add to what Professor Howe has said in the matter, or to make any new contribution to the discussion. I should be very glad to hear from any others present and get their criticism of any of the results which have been obtained and the methods. I may say that the actual curves, cooling and heating curves, are not as satisfactory as I could have wished, as they have been obtained with an apparatus which was in a state of development at the time, such that possibly the cooling curves of this same steel could now be determined with more definiteness and precision than they were at the time they were taken.

K. W. ZIMMERSCHIED, Detroit, Mich.:—The remarks of Professor Howe on the expulsion of ferrite harmonize well with our conceptions of the phase rule. In any stable system composed of two or more phases, these will be separated by definite boundaries, and when we consider that the expulsion he mentions takes place above the *A<sub>1</sub>* point, where we have ferrite separating from martensite, it is evident that all the necessary conditions for the phenomena he describes are present.

If we accept this explanation, it must apply also to other constituents, and we have evidence that it does. Some years ago I was investigating certain parts of the carbon diagram, and had occasion to quench a steel containing about 1.6 per cent. of carbon from above the line of first fusion. It will be recalled that, on cooling, solidification begins at the *AB* line and becomes complete at the *A<sub>2</sub>* line; between these two we have mixtures of solid and liquid, the latter

higher in carbon than the former. On heating, the reverse takes place. Starting at Ac1 with 1.6 per cent. carbon steel, we have first the formation of martensite from the pearlite grains; on raising the temperature this martensite dissolves the excess cementite until a homogeneous solid solution results. At the Aa line (about 1,300° C. for this steel) a liquidus forms, but since this must be higher in carbon than the average of the mass, some local concentration in carbon must take place.

Fig. 15 shows the structure resulting from quenching this steel just above this point; grains of austenite and martensite are surrounded by films of what appears to be carbide or cementite.

Fig. 16, at a magnification of 1,000 diameters, illustrates more clearly what is happening at a point of maximum reaction—that is, the junction of four grains of austenite; the carbide here is draining out of the crystals. On quenching from a higher temperature we get an advanced stage.

Fig. 17, at 500 diameters, shows a decided increase in the amount of liquidus, which, it should be remarked, cannot be quenched fast enough to prevent its separation into two phases resembling ledeburite in structure. Fig. 18, at 1,000 diameters, gives a more intimate view of the situation.

Attention is called, in passing, to the remarkable amount in twinning in the first sample; in some fields on this sample almost every crystal is twinned.

A final test of Professor Howe's hypothesis should be made on hyper-eutectic steel. If such a sample were cooled *in vacuo*, and if the formation of ferrite on the surface in the present samples is not due to decarbonization, we should have in this hyper-eutectic steel an outside layer of carbide.

With regard to Professor Stanfield's remark concerning the proper temperature for hardening hyper-eutectic steel and its relation to the refining of hypo-eutectic steel, we would say, as a result of our experience, that an anneal above the *SE* line may be necessary to refine the grain if it is very coarse, but that such a temperature is wrong for quenching. On holding steel just below Ac1 the cementite agglomerates into spherules between the grains of what becomes globular pearlite, and hardening such material from just above Ar1 results in a martensite with undissolved cementite imbedded in the grains—a structure characteristic of a large class of most successful high-carbon parts.



FIG. 15.—1.6 PER CENT. CARBON STEEL, QUENCHED IN ICE WATER, JUST ABOVE THE TEMPERATURE OF INCIPIENT FUSION.  $\times 500$ .



FIG. 16.—SAME SUBJECT AS FIG. 15.  $\times 1,000$ .

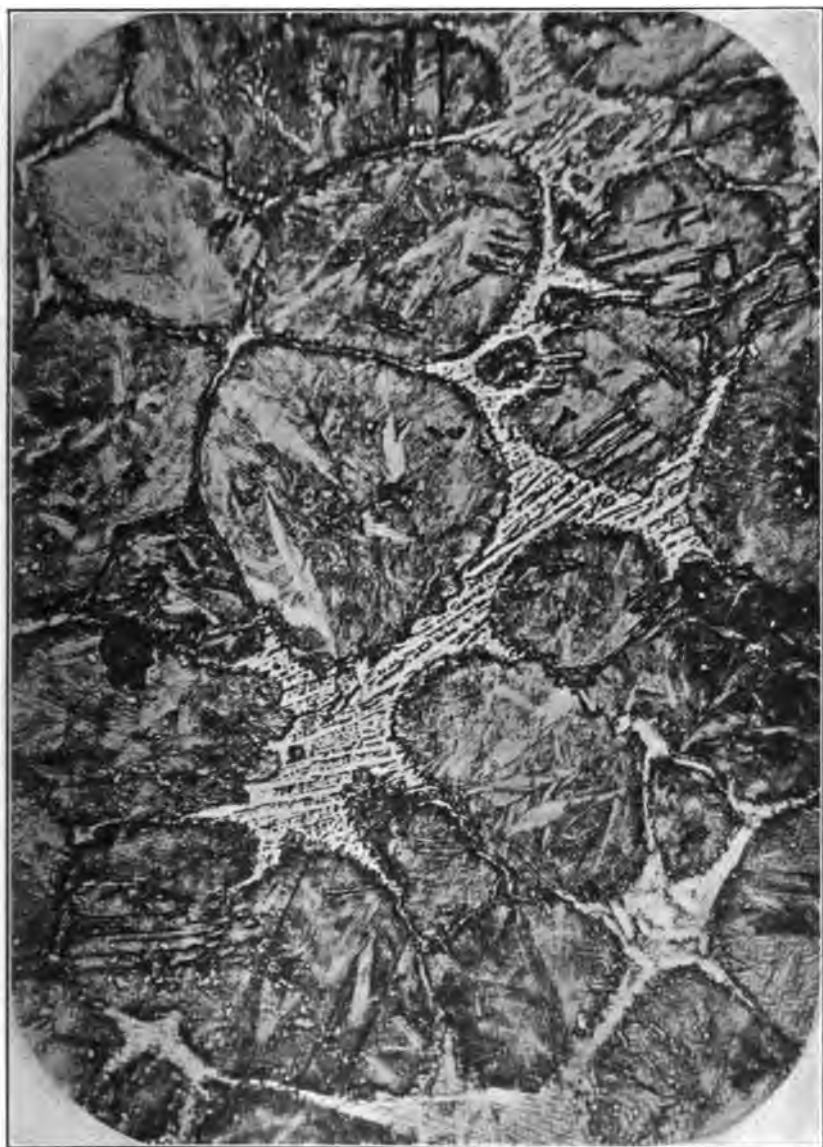


FIG. 17.—1.6 PER CENT. CARBON STEEL, QUENCHED AT MORE ADVANCED STAGE THAN FIG. 15.  $\times 500$ .

coalescence into visibility possible, and the rapidity of cooling there is far greater than in the lower part. Of these 5 sec. not more than a fraction of 1 sec. would in our case be available for coalescence tending towards visibility.

Beyond this, were his objection well founded, then we should have found more ferrite in the axis than in the outer parts of our specimens, because of the slower cooling of the axis. In fact this never occurred. In passing, I am very familiar with Professor Benedicks's classical paper to which Professor Carpenter refers. Indeed it forms a very considerable part of the foundation of my paper, Why Does Lag Increase with the Temperature from which Cooling Starts,<sup>32</sup> in which I set out to explain some of the phenomena which Benedicks there records.

As is pointed out on pp. 1089 and 1123, the alleged quenching ferrite looks very different from the compact spots of pre-quenching ferrite, into which the ferrite precipitated or remanent during our 30-min. holdings coalesced. Short experience will, I am confident, convince any one of even moderate experience with the microscope of the radically different looks of these two. In our precipitation experiments we found it necessary to preheat the specimen to 1,000°, in order to make this difference between quenching and pre-quenching ferrite sharp in the case of the low-carbon steels, as indicated on p. 1079. The difference, which to the eye is striking, is not well shown in a photograph, but a comparison of the sharp dots of pre-quenching ferrite in Figs. A and B of Row 10, Plate 4, with the more cloudy Piece I of Row 14, Plate 5, gives an idea of the kind of difference.

Professor Carpenter is mistaken, I am confident, in holding that the liability to error through the presence of quenching ferrite increases with the carbon content. The opposite is true. Note that the steels in which the supposed quenching ferrite could be detected had 0.40 per cent. or less of carbon. This is primarily because the progressive decrease in the quantity of ferrite precipitable as the carbon content increases retards its coalescence into visibility, and secondarily because the transformation is so much more repressible in the higher-carbon steels.<sup>33</sup>

<sup>32</sup> *Bulletin* No. 75, March, 1913, pp. 479 to 485.

<sup>33</sup> Professor Benedicks refers to finding quenching ferrite in steel of 0.42 per cent. of carbon quenched rapidly from 850°. What he took for ferrite may have been one of those unexplained light-colored bodies such as Heyn noted in what should have been pure martensite. Heyn's light-colored parts were probably lighter-colored martensite which may well be heterogeneous. On pp. 1089-1090 we call attention to white spottings in martensite under like conditions. The martensite quenched from the lower temperature was relatively homogeneous; that quenched from the higher temperature containing spottings which might well be taken for ferrite, but certainly were not, because they troostitized black.



While it is true that the end of  $Ac_3$  cannot be detected as sharply as the beginning of  $Ar_3$ , that consideration is less important than the much greater degree of lag in  $Ar_3$  than in  $Ac_3$ . For our purpose  $Ac_3$  is a better guide than  $Ar_3$  in spite of its being less sharply marked. Beyond this, the  $Ar$  points are likely to be brought below  $Ae_1$  by being not saturation but supersaturation points. That is to say, in the absence of ferrite nuclei, ferrite may refuse even in infinite time to precipitate even well below  $Ae_3$ , precipitating only on reaching the supersaturation temperature, at which from being metastable it becomes labile. That there is such a metastable region between the saturation and the supersaturation lines is strongly indicated by the paper of Burgess and Crowe on The Critical Ranges  $A_2$  and  $A_3$  of Pure Iron, in which they find that, even for zero rate,  $Ac_3$  is invariably higher than  $Ar_3$ .

We have to thank Professor Carpenter for calling attention to errors in Table VIII. These errors do not affect the argument in the least.

The apparently decarburized skin found by Dr. Rawdon after a vacuum heating of a previously untreated specimen (p. 1095) is to be referred, not to decarburization, but to ferrite expulsion. To explain, my theory of the ferrite and cementite network is that each grain of mother austenite expels to its outside the ferrite to which it gives birth, as mothers in general expel their offspring, or as the eye expels a grain of sand. In the crystallization of salts from aqueous and other solutions the same occurs. The salt precipitates along the outside of the liquor, that is to say on the sides of the vessel, on strings or strips suspended in it, and very noticeably on the upper surface of the liquor, each of which is in effect the outside of the liquor, its surface. In like manner the outer surface of a specimen represents the outer surface of each and every austenite grain which abuts against that surface while the metal is above the transformation range.

When in machining the specimen the section cuts through an austenite grain, or the region which an austenite grain will later tend to occupy, that section thereby becomes the surface of that present or future grain, exactly as a string hung in an aqueous solution becomes thereby part of the outer surface of that solution. Therefore when in cooling through the transformation range, an austenite grain, thus abutting against the surface of the specimen, expels to its outside the ferrite which it generates, it expels it perforce to that surface exactly as if that surface were part of the network system, which indeed it is. Hence the border of ferrite about slag inclosures. To test this, speci-



FIG. 19.—HYPO-EUTECTOID STEEL OF 0.40 PER CENT. OF CARBON.

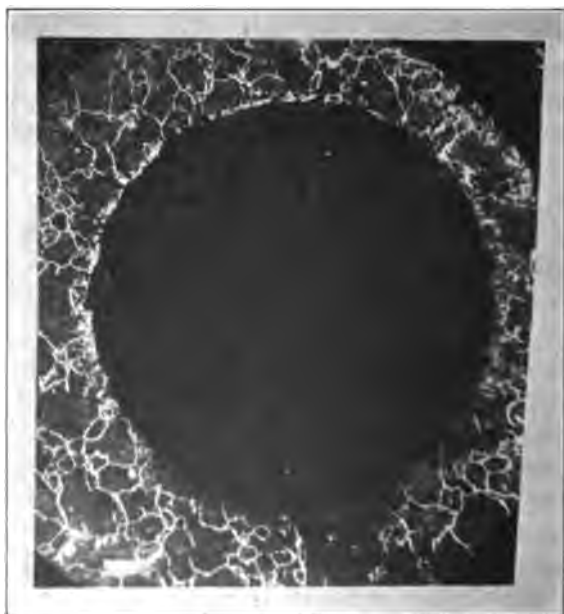


FIG. 20.—HYPER-EUTECTOID STEEL OF 1.45 PER CENT. OF CARBON.

The pro-eutectoid element is rejected to every kind of surface, including internal cavities.



mens of hypo- and hyper-eutectoid steel had small holes cut in them, which were then hammered tightly together and dipped in molten copper to seal them tight. The specimens were then heated above the transformation range in a reducing atmosphere and cooled slowly. The photographs, Figs. 19 and 20, show how the ferrite in the hypo- and the cementite in the hyper-eutectoid steel were thus crowded to the surface of the specimen, *i. e.*, to the walls of the hole. The crowding of the cementite hither cannot represent either local decarburization or local carburization, but parietal expulsion. Dr. Stead has described to me a beautiful experiment in which he crowded the cementite into the weld between two pieces of hyper-eutectoid steel. This local concentration into these artificial grain boundaries seems weaker than that into natural ones.

H. L. LECHATELIER, Paris, France (communication to the Secretary \*) :—I have read with great interest Prof. H. M. Howe's paper on the point A<sub>3</sub>. It constitutes the most important progress accomplished in our knowledge of the equilibrium of the iron-carbon system, since the first researches of M. Osmond. Thermal analysis permitted its author, M. Osmond, to develop quickly the essential points of changes of constitution in steel, as related to its temperature. Following his example the same method was successfully applied, particularly in the laboratory of Professor Tamman at Göttingen, to numerous alloys. This very interesting way of marking out for the first time a field of research, is, however, incapable of giving precise results. The retardations of the transformations, due to passive resistances, so obscure the chemical phenomena within the mass as of necessity to render inexact all determinations made at varying temperature; and the numerous experiments repeated under these conditions have taught us nothing new. Possibly Professor Howe has taken too much pains to analyze and classify the results of these old experiments.

On the other hand, the measurements which he has made by heating to constant temperature present very great importance. His method consists essentially in heating a steel to a fixed temperature for a period long enough to permit the establishment of structural equilibrium; then quenching it in order to fix the structure; and finally annealing it at 350° C., in order to transform the martensite into osmondite (troostite), easily recognizable by metallographic tests.

These experiments established at once, what had not been known with precision before: namely, that heating a steel to a fixed tem-

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\* Received Sept. 17, 1913.

perature for 30 min. suffices to bring it to its state of chemical equilibrium. This is highly important, not only from the view-point of laboratory research, but also from that of industrial operations, because it determines the period, which need not be exceeded, for rendering the metal homogeneous and regenerating its structure, whether after overheating or simply before quenching.

The experiments of Professor Howe enabled him to draw the curve of solubility of ferrite in austenite. According to his paper, the figures are:

|                           |     |     |     |     |     |     |     |
|---------------------------|-----|-----|-----|-----|-----|-----|-----|
| Percentage of carbon..... | 0.0 | 0.2 | 0.4 | 0.6 | 0.8 | 0.9 | 1.2 |
| Temperature, deg. C.....  | 912 | 855 | 800 | 760 | 738 | 730 | 920 |

The determinations for hyper-eutectoid steels are not sufficiently numerous to permit the tracing of the curve of solubility of cementite in austenite to the superior limit, corresponding with the fusion-temperature of the eutectic cementite-austenite. There is room for some new determinations, to determine this second branch of the curve. These experiments are highly delicate, because, in spite of a very rapid cooling, the hyper-eutectoid austenite always decomposes during quenching, and leaves long parallel lamellæ of cementite isolated in the midst of its grains. Thus the structure is not absolutely fixed by the quenching; nevertheless, there should not be very great uncertainty in the interpretation of the results.

The method of Professor Howe permits numerous applications of perhaps still greater importance for the study of non-ferrous alloys. In the case of iron, we know at least in a qualitative way the progress of the phenomenon. There is nothing to do but to determine in addition the points of a curve of solubility, the form of which nobody doubts. This is far from being the case with certain important alloys, like those of copper, and among them most especially, brass. In this last instance, we are not even certain of the exact nature of the combinations formed.

Professor Howe's method is evidently a very slow one, since each sample must be heated half an hour (perhaps longer for the other alloys mentioned) before quenching, and the same operation must be repeated for each of a series of successive temperatures. Time might be saved by making each experiment with a large number of samples, heated at the same time and quenched in the same bath.

It would be possible, even, to operate upon alloys by superposition, the interest of which as a means of accelerating metallographic researches I pointed out long ago. It would be necessary only to scale the superposition at from 1 to 2 cm. of height, so as to be able to cut samples for chemical analyses at the transition-point for the particular temperature of quenching employed.

At all events, the work of Professor Howe constitutes a notable advance in our knowledge of alloys. Apparently, however, after so great a number of researches with regard to them, there were but few new ideas to be brought forward.

ALBERT SAUVEUR, Cambridge, Mass.:—In the work described by Professor Howe in the three papers he presents at this meeting, he has rendered to metallurgists such service as he only could render. The important contributions to metallurgical science from Professor Howe's ever productive and matchless pen constantly add to our knowledge and command our increasing respect, admiration, gratitude, and affection.

The questions which he discusses to-day are not, as he well said, of a purely academic character, for it is of much practical importance to know the exact position of the industrially important critical points.

Daring, indeed, and reckless, the one who would face Professor Howe's formidable battery of facts in an attempt to dislodge from the intrenched position where he has placed them the points  $Ae_1$  and  $Ae_3$ . For my part, I am well satisfied with these positions, and I think they should be used in the construction of future equilibrium diagrams.

The determination of the position of the  $Ae_3$  point by micrographic methods by Professor Howe and Mr. Levy is a beautiful piece of work, indicative of manipulative skill of a high order. The mechanism of the reabsorption of ferrite as hypo-eutectoid steel is heated through its critical range, so well described on p. 1090, is most interesting and suggestive; for upon that absorption depends essentially the effectiveness of the annealing of such steels.

Professor Howe's discussion of the existing data as to the position of  $Ae_3$  is a scholarly production of such nature as to preclude adverse criticism. The author has so well anticipated every possible objection to his treatment of the subject as to afford little comfort to the critically inclined reader,—a feature, it might be added, so characteristic of Professor Howe's writings.

I should like to say a few words in regard to the determination of the line  $SE$ . I should like to call attention to the fact that the determination of that line is not of the same industrial importance as the determination of the  $GOS$  line of hyper-eutectoid steel, because the latter indicates the proper annealing temperature for such steel, it being essentially the refining temperature of hyper-eutectoid steel, and therefore of very great industrial importance. The  $SE$  line is not the refining temperature, industrially speaking at least, of hyper-eutectoid steel; therefore it is not of the same importance. If we

desire to refine, *i. e.*, to destroy the existing coarseness of structure of, high-carbon steel, we heat it slightly above the A<sub>1</sub> point; we do not bring it above the cementite line because we would lose more than we gain. The very small amount of free cementite which is present in such steel is not to be compared, as far as its action on the structure is concerned, with 40, or 50, or 60 per cent. of ferrite in hyper-eutectoid steel. Therefore, should we attempt, in refining, to bring the heat above the cementite line, we would be sure to cause absorption of the cementite, but we would also coarsen the austenitic structure, and therefore the resulting structure after cooling. So it is evident to me that the *SE* line, from an industrial point of view, is not of the same importance as the A<sub>3</sub> line.

There is one more point that I should like to bring out, not that it is not known, but that it is often overlooked, and that is the influence of the temperature from which cooling begins upon the location of the A<sub>1</sub> point. Some of us know that there is such an influence. The higher the temperature from which cooling begins—I think I am right—the lower the position of the A<sub>1</sub> point. We have done a little experimenting at Harvard in that line, and I have some results that appear to confirm that statement.

HENRY M. HOWE:—I have not very much to say, except to say that I am profoundly touched by the kind words that you have spoken.

This matter of the lowering of the recalescence point by reason of higher and higher temperature, that has been shown so very interestingly by Professor Sauveur, was first noticed by Osmond in his original "Transformations." The reason appears to me, as I pointed out at our last meeting here, that at the higher temperatures a greater number of crystalline nuclei are destroyed. That is to say, if you heat only just above A<sub>1</sub> or A<sub>3</sub>, as the case may be, you have a vast number of crystallized nuclei left there; as the temperature rises and as time goes on, those nuclei are destroyed. When you cool down again it is the presence of those nuclei that determines the recalescence. If the nuclei were completely destroyed, you would probably have to go to a pretty low temperature to bring about recalescence. At a temperature only relatively above A<sub>1</sub> there is still an abundance of those nuclei, and the transformation is therefore brought about or precipitated by those nuclei.

I cannot sit down without expressing orally to those who are present my great gratitude for the assistance and support which my collaborator, Mr. Levy, has given me in all this work. It would have been impossible to carry it out without him. His faithful, as well as extremely intelligent collaboration, I want to acknowledge.

## **The Use of Pulverized Coal as a Fuel for Metallurgical Furnaces.**

Discussion of the paper of H. R. Barnhurst, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 82, October, 1913, pp. 2523 to 2532.

H. R. BARNHURST:—I would say that in that experimental furnace we were trying to adopt the proper form for burning low-volatile coal. I was enabled on one occasion to burn coke having 15 per cent. ash. Tailings, or washings from the preparation of coal for by-product coke ovens, which came to me 52 per cent. ash, were burned without any trouble. So that ash really might be regarded as not burning, but simply diluting the fuel that was there, without doing any particular harm except that we had to put in more of the material to get the same quantity of heat. With anthracite, I burned coal right along with from 24 to 27 per cent. ash, but it took a furnace of peculiar form in which the products of combustion had to be diverted to the point of entrance of the fuel. With an ordinary furnace the fuel is deflagrated by its surroundings as soon as it enters the furnace. In a cement furnace this action is secured by the hot clinker passing down, and the walls of the kiln are heated upon contact with it, revolving as they do, so that deflagration occurs very quickly in a cement kiln. Deflagration would occur very quickly in an open-hearth furnace also. There is no trouble in burning anthracite coal under those conditions for three or four days successively. It should be very well dried and thoroughly pulverized. Aside from that, there is no trouble.

WILLIAM A. EVANS,\* Boston, Mass.:—In a 52 per cent. ash, or any high-ash coal, what disposition is made of the ash?

MR. BARNHURST:—Most of it went out through the flues. Some of it remained in the boiler and a quantity remained in the furnace. We raked it out and carried it away.

MR. EVANS:—Do you experience the forming of slags in flues with such coal as that?

MR. BARNHURST:—With perfect combustion I do not think there is any difficulty about slag forming. If combustion is interrupted, then it will slag on most any surface, but if the ash is removed promptly, say within half or three-quarters of an hour or an hour,

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\* Non-member.

the anthracite coal will pass off as a hot dust; but if it stays there longer, it gradually cakes and at the end of three or four hours will become troublesome.

MR. EVANS:—At what temperature will it slag?

MR. BARNHURST:—I cannot say exactly.

MR. EVANS:—I thought the forming of slag over beyond the hearth of the reverberatory furnace would not apply because of the high temperature carrying it beyond the hearth and the forming of a slag with a very high ash coal.

MR. BARNHURST:—I think the slags would vary according to their composition in the furnace. In the furnace I used, the slags did not form at all. As the heat was prolonged the tendency, however, was more manifest.

H. A. PROSSER, New York, N. Y.:—This trouble of slag from the ash choking the flue occurred at Cananea some time ago when they were experimenting with powdered coal. It also occurred at the old Highland Boy smelter, where similar experiments were made. The furnace at Cananea started out very well indeed, and then the tonnage diminished every day, until at the end of three or four days the flue was so filled up that they had to stop the operating.

MR. BARNHURST.—I think a little prevision might have avoided that. The last time I was in the western part of the State I visited an open-hearth furnace that had been running six or eight weeks continuously and had not stopped at all. There was no accumulation that was detrimental at that time.

MR. PROSSER:—The gentleman in charge of both of these plants expressed the opinion that these troubles could be overcome, and since then there have been built two reverberatory furnaces at Copper Cliff which are burning powdered coal; these furnaces have very large flues, and I am told they are running very well indeed. I would like to ask if waste-heat boilers can be used with powdered coal, or whether the dust causes any trouble in the waste-heat boilers of reverberatory furnaces.

MR. BARNHURST:—I see no reason why the dust would not blow out just as freely as in the ordinary type of furnace.

**MR. PROSSER:**—In the ordinary waste-heat boilers on oil-fired copper-smelting reverberatory furnaces the question of blowing the dust off the tubes is quite important; if this is not attended to, the boilers will not perform proper work, and with this powdered coal fuel I suppose you get a great deal more dust in the boilers, so there will be more blowing off to be done. It is rather hard to get the men to do it properly.

**MR. BARNHURST:**—In the Babcock & Wilcox boilers there is generally provision for blowing the boilers off. My experiments were conducted mainly on a Rust vertical-tube boiler and there was no deposit there, nor was there any deposit at the base of the stack. With the fine pulverized coal nearly all of the ash went out. The grosser particles of the coal, those that would not probably pass 100 mesh, would possibly stay in the furnace, and to that is charged the ash that remains there. In burning a ton an hour under a boiler, we did not get more than 30 or 40 lb. of ash, and we could rest for three or four hours and not do anything, but then we found it began to cake and we had to take it out. There was about a wheelbarrow full. We find the best way to get a good constant product is to take it out every hour.

**T. T. READ, New York, N. Y.:**—In the field of copper smelting the metallurgist is confronted by undesirable alternatives. If the coal ash is infusible it will give less trouble through sticking to boiler tubes and flue walls, but it then makes an undesirable addition to the smelting charge. Coal ash from bituminous coal averages about 20 per cent.  $\text{Fe}_2\text{O}_3$  and 35 per cent.  $\text{SiO}_2$ , so that its infusibility is largely due to its high content of  $\text{Al}_2\text{O}_3$  (15 per cent.). The reason why no trouble is experienced on this score at Copper Cliff is because conditions are unusual and the charge is very basic, the slag ranging from 28 to 30 per cent.  $\text{SiO}_2$ . In ordinary copper smelting the metallurgist is between the two horns of the dilemma, and is apt to be impaled on one or the other.

**H. A. PROSSER:**—When slime is used for fettling in copper smelting it very often forms what is called a siliceous blanket over the furnace, and this reduces the tonnage smelted. Usually if you have proper combustion and high enough temperature in the furnace, you can melt this scum. I imagine this trouble they have mentioned, due to the ash falling on the charge, is something of that nature. This trouble was experienced by Sörenson at the Highland Boy, and

by Shelby at Cananea, when firing with powdered coal, but they both expressed the opinion that the ultimate result would be satisfactory if they were permitted to continue to experiment, which they were not.

P. H. GRIFFIN, New York, N. Y.:—I would like to ask Mr. Barnhurst what experience he had in using checker work.

MR. BARNHURST:—My only experience in that has been the observation of two or three open-hearth furnaces where the checker work is used in the ordinary way. No change was made in that. Most of the trouble in using pulverized coal has been from the excessive heat obtained in the beginning, and it is only by providing some way to adjust the air supply carefully that the heat can be kept down. If you merely put in air enough to burn fuel, you will have an excessive heat, giving you trouble.

MR. GRIFFIN:—I asked the question because, of course, it is well known that in the old days when they used cold blast in the blast furnace they got the best quality of cast iron. To-day they are making it in the same way. Now, what would be the effect on the product of the furnace operated in that way if you used the hot blast as compared with the cold blast?

MR. BARNHURST:—I must refer you to Professor Richards's paper.

ALFRED STANSFIELD, Montreal, Canada:—I have recently seen the furnaces at Sudbury, and they were working very well with powdered coal. The ores are not high in silica, and therefore there is not the trouble that has been experienced elsewhere from ashes covering up the slag and making an infusible scum. At the time of my visit, in the spring of this year, boilers were used to recover the waste heat from the reverberatory furnaces fired with powdered coal, and I understand that they were giving satisfaction.

T. T. READ:—I asked the people at Sudbury, and I understood them to say that they had tried waste-heat boilers there and found they cut down the draft too much. It was merely a question of draft, as I understood the man in charge of the plant.

CHAIRMAN RICHARDS:—I have heard from some direction that the use at Sudbury is so successful that the Anaconda Company are going to adopt the same system as that in use at Sudbury in their large reverberatories at Anaconda, where they have boilers for utilizing the waste heat. Therefore their engineers must be convinced that the system will work with their furnaces.



KARL NIBECKER,\* Youngstown, Ohio:—Mr. Barnhurst said that he had burnt coal with a high ash in boilers. I would like to ask whether he has found excessive erosion and wear of boiler and setting with this high ash. Can he tell us the air pressure at which he burned this powdered coal, and what the percentage of ash was?

MR. BARNHURST:—I found that when the blast was brought down to very low pressure and the air blast was but enough to produce the heat desired there was very little trouble.

A MEMBER:—What was the practice observed in open-hearth furnaces?

MR. BARNHURST:—The coal was projected by an 80-lb. air blast through a  $\frac{3}{4}$ -in. pipe. This pipe was surrounded by a pipe 3 in. in diameter through which coal was introduced with air at 1 lb. pressure. That was only putting in about 15 or 20 per cent. of the total air required for the furnace. Using those high pressures you get the long flame that you were speaking of a few moments ago. By projecting the fuel very rapidly and giving it insufficient air at first, you will get a longer flame, because additional air must be taken, as that coal in the core comes to the surface, and is exposed to the oxidizing effect of the air that is coming in. In that way a long flame can be made; but coal mixed with the proper amount of air will burn right back to the nozzle and you will have a short flame and more perfect combustion.

H. A. PROSSER:—In relation to the comparison of fuel oil and coal, the figures were given that 11 gal. of oil are equivalent to 110 lb. of powdered coal. This figures out that from 2,000 lb. of coal you get the same heat effect that you would get from 5 barrels of oil, approximately, and we know, as Mr. Stoughton has said, that in ordinary non-powdered coal practice that figure is from 3 to  $3\frac{1}{2}$  barrels of oil equivalent to 1 ton of coal; this seems to bring out the fact that we get much less efficiency from powdered coal.

R. C. CARPENTER, Ithaca, N. Y. (communication to the Secretary†):—I think that Mr. Barnhurst would confer a favor on the members of the Institute by inserting drawings showing a standard layout of grinding machinery, coal bins, and burners for supplying pulverized coal to a cement kiln. These drawings would give a much clearer idea of the construction than the description.

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\* Non-member.

† Received Nov. 19, 1913.

There is no direct statement in Mr. Barnhurst's paper respecting the explosive nature of coal dust, but in one of his paragraphs a statement is made which has a bearing on this point. Mr. Barnhurst states that pulverized coal should always be handled as a solid and not as a dust cloud. This caution is a very important one to be observed in construction, since coal dust when suspended in air is an explosive mixture which is readily fired, and under such conditions is nearly as dangerous as gunpowder. In the early days of coal-dust burning in the cement industry there were many disastrous explosions, which caused on the whole an extensive loss of life. If the coal dust can be conveyed in such a way that it will not be mixed with air, or at least so that sufficient air for combustion is not mixed with it, there is little or no danger of an explosion. Such conditions will give a slow burning rather than explosive burning and little or no damage is likely to be done.

It strikes me that Mr. Barnhurst's paper does not set forth very clearly the early difficulties that were experienced in coal burning in the cement industry. I spent a great deal of time in developing successful processes of burning pulverized coal in its first application for use in cement kilns. The difficulties were due to many other things than improper grinding, and in addition to developing the proper apparatus quite a long period of education was required to produce skilled men capable of getting results.

The burning of pulverized coal proved to be very different practically from the burning of oil, which had previously been used extensively in the cement industry.

It is interesting to note that up to the present time pulverized coal has not been successfully burned under boiler furnaces, although many thousands of dollars have been spent in the attempt. This calls attention to the fact that the successful burning of powdered fuel needs favorable conditions. The actual combustion must take place with the coal particle in suspension and there must be no impingement of the particle against solid materials, like parts of the setting, until after the combustion is completed. This latter condition is nearly impossible to meet in boiler furnaces. In metallurgical furnaces I believe the success will depend upon conditions. Where the furnace is of such a form that the coal particle can be completely burned while in suspension and before impinging on any portion of the furnace, success may be expected. On the other hand, where the metallurgical furnace is contracted so that solid parts will be impinged on by the flame, pulverized coal will probably not be efficient or successful.

In the cement industry pulverized coal is generally burned with a minimum supply of air; as a rule, the air supply for cement kilns is not regulated but the amount of fuel is varied so as to maintain the highest temperature. Maximum efficiency in cement kilns is usually obtained when a small amount of carbon monoxide appears in the discharge gases, and in many of the cement plants the combustion is regulated to maintain such conditions. This action has the same effect as the regulation of the air, although it can be useful only where there is a demand for all the heat that can be produced.

## The Use of Nodulized Ore in the Blast Furnace.

Discussion of the paper of Robert Henry Lee, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 82, October, 1913, pp. 2515 to 2522.

J. E. JOHNSON, JR., New York, N. Y.:—This subject is of great and increasing importance, as the exhaustion of the deposits of ore of ideal character compels the iron industry to turn more and more to those which are less desirable on account of physical structure as well as analysis. Thus there has come about the use of the Mesabi ores in this country and also of the Minette ores in Europe, which produce far greater percentages of flue dust than did the lumpy ores first used. It is a matter of common knowledge that the utilization of this flue dust, containing commonly 50 per cent. or more of metallic iron, has been a problem very difficult and tedious of solution. The number and variety of the solutions now offered is a sufficient proof of this.

I have no intention of going into the merits or demerits of any of these processes as such, but there are certain considerations concerning the effect of their product on the operation and fuel economy of the blast furnace which I believe to be new and which I desire to bring out.

There are two methods, so different as almost to be direct opposites of each other, whereby an ore may exercise an unfavorable effect on the economy of the blast furnace. The first of these is well known and results from the ore being refractory and highly resistant to the action of the reducing gases of the blast furnace. This results in its being incompletely reduced when it reaches the zone of fusion and in the reduction being finished by the direct action of carbon in the lower portion of the furnace. This is so well understood as to need little elaboration or comment.

There is, however, another action which may be equally as fatal to the economy of the furnace as the foregoing, and as this point is, to the best of my knowledge, not generally appreciated, it is one upon which I desire to lay particular stress. This consists in the ore being, in a sense, too reducible.

A short time ago I received authentic data giving some details of the present operation of one of the largest and best plants in the country. I was struck by two salient points in these data: First, that the fuel consumption averaged about 2,150 lb. of coke, analyzing

88.5 per cent. of fixed carbon; second, that only about 51.5 cu. ft. of air at 60° F. were required to burn a pound of coke. I knew that this plant had formerly made fuel records over long periods of about 1,700 lb. of coke, and while I had no figures of blast required per pound of coke in that practice, I had figures giving this for very similar practice at another plant and at about the same time. This figure was 70 cu. ft. of air per pound of coke.

These two facts, considered in conjunction with some extensive investigations I made earlier in the year concerning charcoal practice, gave the explanation of these two great changes: namely, in coke consumption and in blast requirements.

In the earlier days, before the introduction of the Mesabi ores as a major portion of furnace burdens, the old range ores constituted the principal ore supply. These are exclusively of two kinds—lump and soft—the soft being so sticky that it will stand on an almost vertical slope, and will scarcely run at all. Therefore, when these ores were charged into the furnace they could not and did not run down into intimate contact with the coke, except on the top surface of the latter, with direct contact between the two virtually only in one plane. With the Mesabi ores all this was changed. These ores, being fine and sandy, as soon as they are dried in the upper regions of the furnace run almost like a liquid down through the interstices of the coke as the charges descend and the points of contact between the two are increased to a vast extent.

It is well known that the oxygen of ore in contact with carbon will attack the latter and carry it away with extreme rapidity, irrespective of the composition of the surrounding gas and throughout the entire range of temperatures occurring in the upper regions of the furnace. This well-known action could go on in the older practice only along the single plane of contact between the ore and the coke, but with the great preponderance of Mesabi ores, which run down freely through the interstices in the coke, it can now take place throughout almost the entire coke charge, thus dissolving away a great percentage of the coke in the upper levels of the furnace. This is proved by the small quantity of blast required to burn the coke.

The theoretical quantity required for this purpose may be easily calculated: 2,150 lb. of coke at 88.5 per cent. fixed carbon contains 1,900 lb. of fixed carbon; deducting from this 90 lb. to cover the carbonization of the iron and a little loss through gas escaping around the bosh, we have 1,810 lb. of carbon to be burned per 2,150 lb. of coke charged into the furnace, or 84.1 per cent. of the weight of the coke.

The oxygen required to burn a pound of carbon to CO is  $1\frac{1}{2}$  lb. The air required is  $\frac{100}{8}$  times as much, or 5.8 lb. of air per pound of carbon. As the coke gives only 84.1 per cent. of fixed carbon to be burned, this would require 4.9 lb. of air. Air at 60° F. weighs 0.0763 lb. per cubic foot. Therefore, 64.2 cu. ft. would be required to burn a pound of coke at the tuyeres under these conditions. As a matter of fact, only 51.5 cu. ft., or 80 per cent. of this amount, was required. In other words one-fifth of the whole amount of coke must have been dissolved by the direct action of the ore and carried out the top of the furnace without ever getting into the hearth at all.

It may be well to state here that the figures of blast actually used were obtained by an expert and covered the results of an investigation extending over several years.

If any mistake due to leakage occurred, its effect would be to diminish still further the quantity of air actually used and so make the case stronger instead of weaker.

These figures enable us to determine with considerable accuracy the amounts of carbon actually burned in the hearth in the two cases. For present conditions we have 1,810 lb. of carbon available for the hearth, of which 80 per cent., or 1,450 lb., is actually burned by the blast. In the old practice 1,700 lb. of coke at 88.5 per cent. of fixed carbon gave 1,505 lb. of fixed carbon. Deducting from this 90 lb. for carbonization of the iron, etc., we have left 1,415 lb. Of this we may assume that 5 per cent. was lost by solution by the gas in the upper portion of the furnace, leaving a net of 1,350 lb. to be burned by the blast. This is just 100 lb. less than reaches the hearth under present conditions. The difference is to be accounted for by the relative leanness of the ores used to-day as compared with those used in former practice.

It is commonly considered that the decreased percentage of iron in the ore and the simultaneous increase in silica is wholly responsible for the decline in fuel economy above mentioned, but, in my judgment, this belief is without adequate foundation. It is true that the lumpy ores of Lake Superior averaged at one time almost 60 per cent. in iron and that the average furnace burden to-day averages only 50 or 51 per cent., but this change is due in large part to the fact that the softer and finer ores contain several times as much moisture as the lumpy ores of an earlier day. Five or six per cent. of moisture was normal 20 years ago, whereas many ores to-day contain from 12 to 15 per cent. and not infrequently 5 or 6 per cent. of combined water in addition. The increase in silica has probably not been as great as might appear on casual examination, for the same reason.

It is doubtful if furnace burdens ever averaged less than 5 per cent. in silica and the bulk of the ores in use to-day probably do not average over 8 per cent. It must not be forgotten either that there has been an increased tendency to increase the silica in the mixture deliberately in order to get a larger slag volume, this probably being necessitated by the greater volume of sulphur which the increased coke consumption introduces into the furnace. Looking at the matter from another point of view, it is doubtful if the slag volume per ton of iron to-day is greater than 1,100 or 1,200 lb., and in the old days it was probably never less than 800 lb. Such an increase in the slag volume should produce an increase in the coke consumption of only about 100 lb. as against an increase of four or five times that amount which has actually taken place. For these reasons, the view that the increasing leanness of the ore accounts for the increase in fuel consumption does not seem to be tenable, but rather that the change is caused chiefly by the physical condition of the ore.

I was recently told by some friends that the best figures obtainable from the use of the Dwight-Lloyd cellular sinter in furnaces increased the fuel economy of those furnaces to a greater extent than could be accounted for by the greater richness of the material. I confess that I received this statement at the time with that politely concealed skepticism which is so frequently necessary in such matters, but after realizing the enormous loss caused by excessively fine ores in modern practice it occurred to me that there was probably much more truth in the claims of the advocates of a cellular sinter than I had at first been willing to admit. My experience with the dense varieties of nodules which may be called "artificial magnetites" has been such as to make me extremely doubtful of any claims of increasing fuel economy by their use, especially in conjunction with more reducible ores, but this spongy or completely cellular material must be admitted to have the maximum of advantage from the point of view I have just attempted to bring out. The material is lumpy and angular, and therefore has a minimum of points of contact with the coke, and for this reason the solution loss of the coke must be small, as with lump ores. These properties, due to its peculiar structure, mark it as a distinctly new metallurgical product.

On the other hand, the material is of so open a structure that a gas current can pass through it as freely as the draft passes through it during the process of its production. Its cell walls are extremely thin and therefore its exposure to the heating and reducing action of the gas is a maximum, with a minimum of exposure to the coke, thus simultaneously promoting indirect or gaseous reduction and cutting

off direct reduction through contact with the coke, with corresponding benefit to the fuel economy.

It is easily conceivable that a layer of this material charged immediately on top of the coke would act as a mattress to cut off the passage of finer ore charged on top of it and so promote economy to an even greater extent than the quantity charged would lead one to estimate.

The artificially prepared ores from the rotary kiln have not these advantages. It is true that they are in larger pieces than the fine Mesabias, but their bulk per unit of weight is not nearly so great as that of the cellular sinter, while the small round pellets which comprise so great a portion of the whole mass of nodules are in the ideal state for running down through the coke to the maximum possible extent. On the other hand, the pores which may be formed in this material to permit egress of the gas evolved on heating it are sealed and welded shut by the continual rolling which it undergoes during the process of formation. The nodules also have a minimum ratio of surface to mass; therefore their exposure to the gas is the smallest possible. For this reason this material is likely to reach the zone of fusion very largely unreduced, requiring to be reduced there with direct carbon and high heat.

I have operated a furnace on a mixture of three-quarters brown ore and one-quarter of such nodules, and I know that more fuel was required as well as greater time in the furnace and consequent reduction of output, though the furnace was very slowly driven to begin with.

Considering these facts, it seems to me likely that a burden of a cellular sintered material should give better fuel economy than either fine reducible ore on one side or nodulized ore on the other. The figures that I have given above from actual practice show the loss resulting from the use of fine ore, and are an indication that this saving may be of very great commercial importance. They suggest that making a cellular sinter of the fine portions of Mesabi and other ores and concentrates would effect a great economy in the furnace, in spite of the current opinion on the subject. It points a way toward attaining the low fuel economy of 20 years ago.

HENRY M. HOWE, New York, N. Y.: If that theory were true, wouldn't it be immediately reflected in the compositions of gases? Wouldn't you have an immediate check on that theory in that way?



J. E. JOHNSON, JR.:—Any change in fuel economy is always shown absolutely in the composition of the top gases, but we have no means of distinguishing oxygen which comes from the air from oxygen which comes from the ore, and consequently low  $\text{CO}_2$  in the top gases does not indicate whether we have a high solution loss or bad hearth conditions. The top-gas analysis is only an indication of a condition which shows itself much more quickly and plainly in other ways than it does in the gas analysis.

## The Critical Ranges A<sub>2</sub> and A<sub>3</sub> of Pure Iron.

Discussion of the paper of G. K. Burgess and J. J. Crowe, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 82, October, 1913, pp. 2537 to 2591.

HENRY M. HOWE, New York, N. Y.:—I think we can hardly overrate the importance of the entry of the Bureau of Standards into our field. There is no body in the world that is better fitted to undertake this work than that Bureau, and it is work which really calls for the aid of some national organization. The skill and care with which this work has been done speaks for itself.

It is very striking that within a very few months the distinguished English investigator, Professor Carpenter, of whom I spoke before, thought that he had disproved the existence of beta iron by proving that the A<sub>2</sub> retardation which Professor Burgess has now demonstrated did not occur. Dr. Burgess's demonstration of the existence of this retardation makes the existence of beta iron very probable, in my opinion.

Osmond used to call beta iron "decipuum." You knew of its existence as you know of the existence of certain planets, only by the perturbation which it caused. Certain phenomena could not be explained, except by assuming the existence of a third allotropic form, beta iron. The evidence that you got was always evasive and susceptible of other explanations, except that which we have to-day, which it seems to me is not capable of other explanation.

Professor Carpenter proceeded in the same way that Dr. Burgess has, by taking the heating and cooling curves of exceedingly pure iron, and thought that he had shown that there was no thermal change, no absorption or evolution of heat at the supposed A<sub>2</sub> point, and hence that the A<sub>2</sub> point did not exist. This he did by a piece of reasoning which I think seems to most of us rather surprising. That is to say, if of ten witnesses, three have seen a thing and seven have not, the evidence of the seven who have not is set aside, and that of the three who have seen stands. In Dr. Carpenter's own experiments under certain conditions he found the A<sub>2</sub> change, the heat evolution; under certain others he did not. That is like the three witnesses who saw and the seven who did not see. You can arrange your test so that this change will not become visible or so that it is masked. But though an existent change can be masked a non-existent one cannot be shown. So that the reasoning seemed to me wholly fallacious.

Professor Benedicks started some months ago, about a year ago, to call our attention to the fact that our ideas of allotropy were very much mistaken in one respect, that we looked at an allotropic change as something which must needs occur at a definite temperature. Water freezes at zero and boils at 100. That was a very natural conception when we first thought of allotropy, and only had the allotropy of carbon, sulphur, phosphorus, those very striking cases, in mind; but now we find allotropy on every hand.

There is no question, I suppose, now that water above the freezing point consists of water with ice dissolved in it. As the temperature shifts you get that reversal of density above the freezing point. That reversal, which is a progressive and not an instantaneous one, means that the quantities of water and of ice present—not visible ice, of course, but ice dissolved in water—change progressively through a continuous smooth curve. By means of a like case of allotropy Professor Benedicks brought attention to the fact that these allotropic changes may be continuous, they may be spread out through a range of temperature, and may occur through a perfectly smooth curve, giving no sign of their existence to a superficial observer.

What Professor Carpenter did was to cause the A2 or beta allotropic change to take place through so smooth a curve that in many cases no break was detected. He assumed that, because he did not always detect a break, there was no allotropic change, which was not good reasoning. Failure to detect a break might represent either (1) absence of an allotropic change, or (2) the presence of an allotropic change, occurring so progressively and continuously that (a) it caused no break, as none is detected in passing the maximum density of water, or finally (b) that the break caused could not be detected under the special conditions of the experiment. The fact that Dr. Burgess now detects this break with absolute certainty shows that this last is the reason why Professor Carpenter failed to find a break under certain conditions; his method, though sensitive, was not sensitive enough.

ALFRED STANSFIELD, Montreal, Canada;—I have great pleasure in expressing my admiration for the work of Dr. Burgess, and I am interested to learn something more about the point Ar2.

A number of years ago I showed the existence of this point in electrolytic iron, which was deposited directly on the thermocouple to avoid the possibility of any carbon entering it. At that time we were not beyond reproach in the matter of gases present in the iron, although a good deal of hydrogen was removed by heating *in vacuo*;

but as the Ar2 point was observed at the same temperature in low-carbon steel it did not seem possible that hydrogen could cause this evolution of heat. Experiments with mild steel showed that Ar2 was not due to hydrogen, and experiments with electrolytic iron showed that it was not due to carbon or other impurity, so that we had no doubt that Ar2 was an evidence of some change in the iron itself.

I was therefore surprised to learn that the authenticity of the Ar2 point has been called in question, and I am glad to see that it has been resuscitated and properly authenticated. In my experience I found the Ar2 point not only on the line *MO*, but also following a continuation of this line to the right of *O*. I supposed that this was due to the irregular distribution of carbon within the mass. Perhaps the external portion of the steel was somewhat decarburized, and that would give the Ar2 point when the average carbon content was over 0.45 per cent.

In regard to my discussion of Professor Howe's paper, I should say that the work to which I was referring was of a very unusual and entirely uncommercial character. I was working on the burning of steel. All the steel specimens were carried up into the range *AaB* and deliberately burned. Steel having 1.5 per cent. of carbon showed a very coarse crystalline fracture; great leaf-like crystals could be seen with the naked eye spreading over practically the whole surface of the fracture. In order to break up that structure and restore to some extent the fineness of the grain, I found it necessary to reheat the steel to the line *Sa*. That seemed to be the only way to obtain any reduction of the size of the grain by heat treatment alone, although it was of course impossible to obtain a very fine grain by heating the steel to this temperature.

A. A. STEVENSON, Philadelphia, Pa.:—I would like to call attention to a point brought out by Professor Le Chatelier calling attention to the industrial value of time limit, as determined by Dr. Howe, for holding the piece at a fixed temperature. As I understand it, Dr. Howe's experiments were made with pieces of small mass. The time required to give the best results will depend largely on the mass of the piece. Dr. Burgess tells me he hopes to conduct some experiments at the Bureau of Standards, using samples of dimensions such as we have to deal with in commercial work. The results of such experiments will certainly prove of interest and value.

BRADLEY STOUGHTON, New York, N. Y.:—I can testify to that in confirmation of what Mr. Stevenson says. I know that the makers

of cast-steel rolls of very large diameter heat them up for several days, and even after that treatment when the neck of the roll is broken off they often find a section in the very center which is not refined. Of course, theoretically that is impossible, because the heat conductivity of the iron should certainly carry the temperature into the center of the roll in a very short time. But unfortunately the people who buy and pay for the rolls are not theorists, and they will not accept the academic ideas on that subject. If a roll is broken and is not refined in the center it is rejected and it is a cause of pretty serious loss to some of the steel foundries. So it would now be a very valuable contribution to our knowledge if we could get some idea of how long it is necessary to heat large masses of steel in order to refine them to the center.

A. A. STEVENSON:—Referring to what Secretary Stoughton has said, in my opinion the question of time required to heat up should not alone be given consideration, but also the effects of various lengths of time in cooling.

PAUL WEILLER, Perth Amboy, N. J.:—One of the most important of processes is just the rolling of heavy steel, and this rolling is going on nearly always between the critical ranges of temperature. It seems to me it would be very important to know how critical temperatures are affected by high pressure occurring in rolling. Everybody knows that in rolling a good many phenomena are observed that were hardly explained till now. I think an investigation in this line would be very useful.

As to the definition of allotropy, this has been done in a very exact way by Willard Gibbs and Bakhuis Roozeboom. Every allotropy is connected with a definite vapor pressure for a definite temperature, and different allotropies, of course, have different vapor pressures for the same temperature, and the crystal form is wholly incidental. It might be that two different allotropies have the same crystal form. It is not the rule, but it may be. From every temperature the allotropy with the lowest vapor pressure is the stable form and all the others are instable.

P. H. GRIFFIN, New York, N. Y.:—It is important to secure, if possible, the interest of manufacturers in the work that has to be done. I think many of the gentlemen present have had some experience with the attitude in the past of some of the larger manufacturing institutions toward work like this. I think this work is the most

important that has ever been taken up in this country. That is to say, it is coming out at a time when there is more of a disposition on the part of all concerned to take it favorably, to get in connection with it. I have had considerable experience in practical manufacturing, and know more or less of the attitude of practical manufacturers toward work of this kind, and the difficulty always has been to get them to realize its value and importance. I think that is due to two facts. The first one is that naturally a good deal of it is Greek to them. They are not chemists, they are not men who understand the terms and other things that they have to understand to keep in touch with the work. And then again a great deal of work is done by practical men, who, generally speaking, have the idea that practice and theory are two such totally different things they never will come together. So far as the work of the Bureau of Standards is concerned, it is really the only place in this country where something of this kind can be done after the work of the different institutions has been brought together. This is by far the largest and most important subject in the whole history of iron and steel in this country—that is, in its possibilities. I want to emphasize the need of getting the co-operation of bodies or associations of manufacturers or others; and particularly of the mechanical men in them, the men that do not very often get into these meetings, because they can throw a great deal of light on this subject if you can only get them to talk. They can tell you their experience in working large amounts of these materials. If you can get those men to take that action it will make a sort of public opinion back of the work that the Bureau of Standards can do. The Bureau of Standards is a branch of the Department of Commerce, and the Department of Commerce has to have some backing to do this thing. It is more or less like what the Agricultural Department is doing for the farmer, and the iron and steel manufacturers are getting more or less into a position like that of the farmer where they are asking the co-operation of bodies like this one and of the government.

CHAIRMAN SAUVEUR:—I am sure that we do desire the co-operation of all iron and steel makers if we want to get results. Meanwhile I think we are extremely fortunate in having the Bureau of Standards ready to take up these important questions, and I for one will look forward to extremely important contributions from them.

The Institute is to be congratulated on having secured for permanent record in its *Transactions* a paper of such importance and timeliness. Dr. Burgess and Mr. Crowe's work in demonstrating, beyond

any possible doubt, the independent existence of the A2 point will be most weighty in settling a controversy which it was highly desirable to settle. It is well known that for many years some metallurgists have doubted the allotropic character of the A2 point, some indeed going so far as to question its very existence. At the Fall, 1912, meeting of the Iron and Steel Institute, Professor Benedicks outlined a theory based on the assumption that the Ar2 point indicated the end of the Ar3 transformation, some gamma iron remaining untransformed (and therefore in a metastable condition) below Ar3, through the influence of impurities. The theory demands the absence of both Ar2 and Ac2 points in absolutely pure iron and the absence of the Ac2 point even in impure iron. At the May, 1913, meeting of the Institute, Professor Carpenter called attention to the above requirements of the theory and reported that he had indeed shown the non-existence of the point Ac2 in impure iron. As to the non-existence of the Ar2 point in strictly pure iron, since such metal cannot be produced, this claim of the theory cannot be tested. In Professor Carpenter's opinion the results of his experiments justified the following statement: "The conception of A2 as an independent allotropic change must be abandoned, and it must now be regarded as proved that Ar2 is simply the termination of Ar3 retarded by impurities present even in the purest forms of iron hitherto prepared." So sweeping a conclusion based on a few experiments, the results of which were opposed by those of all other investigators, was taken exception to by nearly every one discussing Professor Carpenter's paper. This led him to modify his views as follows:

"Summarising the position, therefore, and having regard to the case not only that other investigators have found Ac2 even in the purest samples of electrolytic iron hitherto prepared, but also that facts have been adduced in the discussion which are difficult to explain on the hypothesis that A2 is retarded A3, the author desires to modify his conclusion that 'the conception of A2 as an independent allotropic change must be abandoned,' and to say that 'the present state of knowledge does not justify this conclusion.' At the same time he considers that his own results detailed in the paper appear to him to be most satisfactorily explained on this hypothesis."

At the September, 1913, meeting of the Iron and Steel Institute, I expressed the belief that the burial of beta iron had been premature, giving in support of my contention some results of my own experiments. After reading the paper now under discussion I am more convinced than ever that Benedicks's theory will have to be deeply modified if it is ever to displace Osmond's original theory. The

authors have taken in vacuum and with the greatest refinements some 180 heating and cooling curves of the purest irons obtainable, including a specimen of Professor Carpenter's own metal, and never failed to detect a marked evolution of heat at Ar2 and marked absorption at Ac2. They have proved the independent existence of Ac2 and Ar2 in a way that is absolutely conclusive. To the contention, should it still be made, that in strictly pure iron the point A2 would not occur, it may be replied that the fact that the point Ar2 does not decrease in intensity as purity increases is quite conclusive proof that it would not suddenly disappear with absolute purity. Its disappearance must of necessity be a gradual one.

As the authors well say, whether the A2 point marks or not an allotropic transformation is, to a great extent, a question of definition. If it be insisted that allotropy necessarily implies a change of crystalline forms, then it may be argued that A2 is not an allotropic point. If, on the contrary, it is believed that a change of internal energy, made evident by spontaneous evolutions of heat, is the criterion by which we should determine the existence of allotropy, then A2 indicates an allotropic transformation. The latter view is strengthened by the discontinuity in some of the properties of iron at the A2 point, especially by the magnetic change occurring at that point.

ROBERT W. HUNT, Chicago, Ill.:—I would like to add just one word on the commercial side, particularly in relation to the Bureau of Standards. It is no idle word that the work should have the emphatic encouragement of our Institute, and of every other scientific and commercial organization in the country. Unfortunately, while they can investigate to a great extent, their voting power is a very limited one, with the result that they are not close to the hearts of the law makers of our country. I have had experience in that line in regard to the effort to establish a national testing laboratory, having appeared before the Congressional Committee on Appropriations. Indifference and want of comprehension of the necessity for such national organizations have generally existed with the American law makers, and they need our sustaining hands. One of the most important steps that have been taken in this country is to recognize the necessity of such a Bureau, and our representatives ought to be made to feel that it is just as much their duty to vote for proper appropriations for such work as for battleships or armies.

G. K. BURGESS:—I would like to express my appreciation of the sentiments that have been stated in the discussion of this paper, and



also I shall take to heart the several suggestions that have been made regarding the work that should be done, which is demanded by the several members of this society; as, for instance, the effect of mass and pressure and the other items which have been mentioned regarding the study, for instance, of the iron-carbon diagram. I also assure you that I will go back to Washington encouraged to go on with this work with as much effort as will be put at our disposal for carrying it on.

CARL BENEDICKS, Stockholm, Sweden (communication to the Secretary\*):—1. The great merits of this paper are so obvious that they need not be emphasized; it marks a record in giving accurate figures under definite circumstances, and must be most welcomed by every one. It could possibly be suspected that exception might be made for the present writer, and also for Professor Carpenter, as a glance at the exuberant collection of curves seems to reduce almost to *nil* the value of the beta iron theory advanced by the writer, and as Plate VI shows the most clear heat absorption at Ac2 where Professor Carpenter could not find any heat absorption at all.

To judge from some expressions, the authors had a certain disregard for theorizing. The essence of our science, however, is a well-balanced equilibrium between laboratory work and pure brain work. While I am now going to increase that "amount of theorizing," the fact is that the amount of new experimental work before us makes me feel justified.

2. In every case known as yet, even in the cases of homogeneous equilibrium studied by Professor Smits, an allotropic change is a molecular change—viz., a *chemical* change from one kind of molecules to another—and involves regularly a true recrystallizing. Such a molecular change or recrystallization always proceeds at a comparatively low speed. A consequence of this is that, *without exception, an allotropic transformation point is found at a higher temperature at heating than at cooling*. Now, this is obviously the case for A3; compare especially the excellent Fig. 7, giving evidence not only that A3 is displaced, but also that it is displaced all the more, the greater the speed of the temperature change is. (I am not convinced that the lines drawn on Fig. 7 should necessarily be straight lines; there is a possibility that they should be replaced by gently bending curves meeting at the temperature axis; as drawn, the straight lines signify the occurrence of a "false equilibrium" of Duhem, which has not been definitely proved in a single case.)

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\* Received Nov. 29, 1913.

3. Now, the most important point borne out in the paper is, so far as allotropy is concerned, *that A<sub>2</sub> is always found at exactly the same temperature*, and is not at all influenced by heating or cooling speed. This is a proof as good as any that the phenomenon investigated here and designated as A<sub>2</sub> is *not a chemical allotropic point* (involving molecular change). Had the authors, on the iron freed from gases, traced the slightest lag in the position of A<sub>2</sub>, there would be a possibility of admitting a distinct chemical allotropic point. Instead, A<sub>2</sub> is determined with the monumentally accurate formula  $Ac_2 = Ar_2 = 768^\circ \pm 0.5^\circ$ , allowing of no lag.

The question then arises: if, on this ground, A<sub>2</sub> cannot possibly signify a true allotropic change, what might be the secret nature of this A<sub>2</sub>, immovable and enigmatic as a Sphinx?

4. We then proceed to an inspection of the registered curves. Leaving out of regard the good agreement between the I and D curves, and that astonishing constancy in the position of A<sub>2</sub>, the cooling curves do not show any new facts, not known by the previous work of Osmond and others. The amount of heat connected with Ar<sub>2</sub> seems to be little in comparison with that of Ar<sub>3</sub>, just as found by nearly all previous workers (the curves below and above Ar<sub>2</sub> on all the plates lying tolerably in the same extension).

On the contrary, the heating curves all have a common character which is novel and not met with in any previous research known to the writer. I mean the very abrupt deviation to the left, or back swing, of the heating curves, occurring as soon as Ac<sub>2</sub> is reached. The part above Ac<sub>2</sub> lies, in fact, very much to the left, signifying an *enormous, continuous heat absorption above Ac<sub>2</sub> (or heat development in the specimen below Ac<sub>2</sub>)*; the heat development at Ar<sub>2</sub> is entirely beyond comparison with this. This singular fact is slightly touched upon by the authors on p. 2572, just before concluding. If I have correctly grasped this passage, which I do not find quite clear, the authors consider that "this long back swing appears to be in part at least a property of the heating conditions"; they thus seem to attribute the abnormal behavior of the curves to *irregularities in the heating*. On the other hand, on p. 2555 special mention is made of the rheostat used, as giving "automatically a constant rate of heating and cooling." The contradiction seems to be an unmistakable one, especially as a constant storage battery was used.

5. Following the suggestion of the authors as to some unknown or not observed influence of the heating, we now proceed to a critical discussion of the energy supply. It is correctly stated that a magnetic field might influence the magnetic transformation. On the other hand,

the assertion is made that an alternating current "eliminates any magnetic field about the iron sample." Now, it is not necessary to refer to the illustrious experiments of Tesla; it might be enough to refer to the much more prosaic experience of the unwelcome heating of iron transformer plates. At each magnetizing cycle, as is well known, a certain quantity of heat is deliberated in every ferro-magnetic substance—the hysteresis coefficient may be as low as possible, the iron as pure as conceivable. The energy supply being very high, and the platinum being wound in two layers, the reversing magnetic field by no means can be neglected, without special precautions which are not mentioned. Let us follow the heating up of a specimen. Being strongly ferro-magnetic, it receives constantly a certain amount of hysteresis heat (besides eddy currents), which per minute might be of the same order of size as, say, the heat development at Ar3. But, as is well known, the ferro-magnetism disappears rather quickly in a narrow temperature range. The consequence is, that this interior extra energy supply must disappear rather suddenly. In the heating curve this must necessarily appear as a strong heat absorption,—which has nothing direct to do with allotropy.

In the cooling curves this extraneous effect must be less pronounced, as the current generally is less on cooling than on heating.

Further, the magnetizing velocity of iron being known to be extremely high, it does not seem unreasonable *a priori* to admit that the passage of the iron from the ferro-magnetic state to the para-magnetic one, and *vice versa*, might also occur with a very great velocity, much superior to the velocity of recrystallization at Ac3. Thus, if the heat developments observed as Ac2 and Ar2 by the authors in fact are due to "heat of magnetization," then it is very natural that no trace of lag is observed ( $\pm 0.5^\circ$ !).

It is not possible for me here to go more into details. It is quite possible that my view on this question is not correct, but, from the facts and description as given in the paper, no other explanation seems to me to be possible. In order that the conclusions could be correct, it seems quite necessary, until the authors prove the contrary, to have in view that their observations are valid only in a reversing magnetic field.

In view of this it might be reasonable to add that the failure of Professor Carpenter to find any Ac2 in his purest specimens, on which a very clear Ac2 is indicated on Plate VI, needs not to be caused by his method failing in accuracy, but might entirely be due to the absence in his work of the very serious source of error involved by the use of alternating current.

6. Finally, I do not consider it justified to assert that "the only phenomenon studied which has hitherto always given negative results for A2 is crystalline structure" (p. 2549; similar statement, p. 2570); it is necessary at least to add that this is also the case with the *expansion*, all the more as this property is extremely important, its measuring being much more reliable and less affected by sources of errors than probably any other property.

Summing up: in spite of the very elaborate and careful experimental work now carried out with well-known thermometric mastership, and so ably presented as an apparent support to the old allotropy views—even if the authors have hesitated in expressing an opinion on the nature of the allotropy—there is, at present, no ground for modifying the allotropy theory as advanced by Smits and, particularly for iron, by the writer.

H. C. H. CARPENTER,\* Manchester, England (communication to the Secretary \*):—I wish to offer my very cordial congratulations to Messrs. Burgess and Crowe on their paper entitled *The Critical Ranges A2 and A3 of Pure Iron*. There can be no question but that in point of thoroughness and accuracy it is the best investigation of this problem that has ever been carried out. I need hardly say that the research has a special interest for me, inasmuch as I have myself been recently working in the same field and have come to a different conclusion with regard to the character of the A2 inversion.

Let me begin by saying that the evidence that there is a discontinuity at  $768^{\circ}$  on the heating curves of pure iron appears to me to be conclusive and indeed overwhelming. Further, I am entirely disposed to agree with the reasons that the authors have suggested as to why I was unable to detect with certainty the Ac2 change in the specimens of iron with which I worked. The evidence offered by them that this was due to "the poorer conductivity and the presence of gases in the wound-up sheets of otherwise untreated electrolytic iron producing a flattening out, distortion, and displacement" of the Ac2 change appears to me to be very strong. At the same time, however, my results as to the location of Ac3 and Ar3 are in very fair agreement with the conclusions of Messrs. Burgess and Crowe.

Before discussing the interpretation of the discontinuity found by the authors at  $768^{\circ}$  I should like to draw attention to several points of importance which they have established.

1. *The Effect of Occluded Gases*.—This research has shown for the first

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\* Non-member.

† Received Dec. 1, 1913.

time what this effect actually is, and that if accurate results are to be attained the most suitable procedure consists in premelting the iron *in vacuo*, of course under conditions which will as far as possible avoid contamination.

2. The authors are to be specially congratulated on having obtained satisfactory curves with very small samples (whose weight was of the order of 1 g.). It is quite intelligible why sharper indications of the critical range are thus obtained. I have been particularly interested in the curve F5, of my own sample of iron, obtained with 0.7 g.

3. The thanks of all metallographers are due to the authors for having worked out for the first time the effect of different temperature intervals on the form of the curves (Plate III.) and for having shown that a 2° interval is a satisfactory mean. Another very useful conclusion which they have established is that the inverse-rate and derived-differential curves are strictly similar "save for minor particulars" and "give identical results of the same sensibility for the critical ranges."

4. I am very glad to notice the authors' conclusion that "the A2 transformation has not a double cusp." It has always appeared to me as probable that when a double cusp was obtained this was due to a too rapid rate of cooling.

I come now to the question of the meaning of the discontinuity shown on both the heating and the cooling curves at 768°. The authors say: "An examination of some of the heating curves will perhaps give the incorrect impression that Ac<sub>2</sub> is an evolution rather than an absorption of heat. The swing back at the maximum is very abrupt, following what appears to be a general building up . . . from an indeterminate low temperature." An examination of both the heating curves of F5, Plate VI. (my own iron), shows that they are reasonably smooth up to 768° and that there is then a sudden acceleration in the rate of heating. This means either the sudden cessation of an absorption of heat (whose beginning it is impossible to detect) or else an actual evolution of heat. I do not think it is possible to say dogmatically which of the two hypotheses is correct, and for the purpose of my argument it does not matter, but I will take the authors' view that this discontinuity is not an evolution of heat, but corresponds to the cessation of some change which has been proceeding "from an indeterminate low temperature." The cooling curves, however, show that there is an actual evolution of heat at 768°—viz., at the same temperature as on the heating curves. How then is it possible to regard the discontinuity at 768° on the heating curve as corresponding to the discontinuity at 768° on the cooling curve,

since, according to the authors' view, the change begins on heating at a temperature *below* that at which it occurs on cooling? This seems to me to be impossible, and I should be glad if the authors would explain how they can reconcile their interpretation of the curves with the evidence of their own paper.

As a matter of fact, although the authors have undoubtedly established a sharp discontinuity on the heating curves at  $768^{\circ}$ —a result which my own curves do not show—nevertheless their conclusion that there appears to be a gradual building up of this maximum from an indeterminate low temperature is really very much the same as my own (No. 2):<sup>1</sup> "There are traces of a retardation in the rate of heating spread over a considerable temperature interval, which might be expected to include Ac2 within its limits if it existed." In this important respect, therefore, the authors' and my own curves are in undoubted agreement. The question which has yet to be answered and which future research must decide, is, why is it that there is nothing on the cooling curves to correspond to the gradual building up of a maximum over an indeterminate range shown on the heating curves? If the authors can furnish the solution to this question they will render very great service to all those interested in the allotropy of iron.

In conclusion, it is a matter of considerable interest to me to observe the most probable values assigned by the authors to Ac3 and Ar3. The former they regard as taking place at  $909^{\circ} \pm 1$ . My recent research with Dr. Stead on The Crystallising Properties of Electro-deposited Iron showed that at  $910^{\circ}$  the recrystallization of iron has just begun, and is complete at  $915^{\circ}$ . Also, my heating curves (Plate LII. of my paper on The Critical Ranges of Pure Iron) represent the thermal inversion as taking place at temperatures between  $902^{\circ}$  and  $916^{\circ}$ , giving a mean figure of  $909^{\circ}$ . This agreement is very satisfactory. Again, the authors place Ar3 at  $898^{\circ} \pm 2$ . The figure I obtained with Mr. Keeling in 1904 was  $900^{\circ}$ , which agrees rather better than the figures given in my recent paper, which vary between  $898^{\circ}$  and  $886^{\circ}$ .

There are other matters in the authors' paper which I should have liked to discuss had time permitted, in particular the thermal lag which undoubtedly exists during the A3 inversion. It is not large, in fact it is only of the order of about  $5^{\circ}$ , but it is a real lag. I am very much inclined to agree with their suggestion that this is bound up with the remarkable recrystallization associated with this change

<sup>1</sup> The Critical Ranges of Pure Iron, *Journal of the Iron and Steel Institute*, vol. lxxxvii (No. I, 1913), p. 324.

shown by Dr. Stead and myself, but more research is required before the connection can be regarded as scientifically proved.

G. K. BURGESS, Washington, D. C. (communication to the Secretary\*):—The authors welcome and appreciate the contributions to the discussion of their paper by Messrs. Carpenter, of Manchester, and Benedicks, of Stockholm. They note with particular satisfaction that Professor Carpenter, who has contributed by experiment to our knowledge of the properties of iron and by close reasoning to the theory of its allotropy, agrees without reserve to the main conclusions of the paper concerning the separate existence, location, and nature of A2 and A3, and accepts the explanation therein given for his failure to locate satisfactorily the Ac2 change in the specimens of iron with which he last worked. They are also greatly obliged to Professor Carpenter for so clearly summarizing the several points of importance which the authors have established.

Professor Carpenter very pertinently raises the question of the meaning of the discontinuity shown in both the heating and the cooling curves at 768°, and asks "if the authors would explain how they can reconcile their interpretation of the curves with the evidence of their own paper." (See p. 2572.)

The authors would like to state at the outset that they are ready to accept what may appear to be the most rational interpretation of these heating and cooling curves for pure iron, whether coming from themselves or some one else. The only point on which they have any particular sensitiveness is the question of the exactness of their measurements, which is not raised by Professor Carpenter.

It does not seem to the authors, however, that there is any greater difficulty in explaining the heating curves in the Ac2 region than in the Ac3 region; for an examination of the heating curves on several of the plates, notably Plates III, IV, IV<sub>A</sub>, V, etc., shows that the "abrupt swing back at the maximum" is at least as pronounced and as often unaccompanied by an absorption cusp at Ac3 as at Ac2, as the authors endeavored to point out on p. 2572. It was also there stated that "this long back swing appears to be in part at least a property of the heating conditions." From this expression, it is by no means to be inferred, as Professor Benedicks would have it, that "they [the authors] thus seem to attribute the abnormal behavior of the curves to irregularities in the heating."

These curves have no "abnormal behavior." It is to be remem-

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\* Received Dec. 2, 1913.

bered that the cusps of the I and D curves correspond to the instant at which the temperature of the sample, as measured by the inserted thermocouple, is changing the least. The actual shape of the I and D curves in going through a transformation will depend therefore upon the conditions of transfer of heat between sample and furnace, and sample and thermocouple; which conditions, as is readily seen, are essentially different on heating and cooling, a fact which appears to account for the lack of symmetry in the form of  $\text{Ac}_3$  compared with  $\text{Ar}_3$ , and  $\text{Ac}_2$  with  $\text{Ar}_2$ . The authors can see no incongruity in regarding "the discontinuity at  $768^\circ$  on the heating curve as corresponding to the discontinuity at  $768^\circ$  on the cooling curve," even if it be admitted that "the change begins on heating at a temperature *below* that at which it occurs on cooling." A similar thermal condition exists in the melting and freezing curves of innumerable slightly impure substances without exciting particular comment; the maxima (Ac, Ar) are at the same temperature and Ac begins well below its maximum. It is the view held by the authors, and satisfied by the curves in the paper, that both  $\text{Ac}_2$  and  $\text{Ac}_3$  are built up gradually from temperatures somewhat below their respective maxima. The reason "why it is that there is nothing on the cooling curves to correspond to the gradual building up of a maximum over an indeterminate range shown in the heating curves?" asked by Professor Carpenter, appears to be simply this, that the "swing back" on cooling below the maximum of  $\text{Ar}_2$  or  $\text{Ar}_3$  cuts into this "building up" region, as it must (corresponding to the "swing back" immediately above  $\text{Ac}_2$  or  $\text{Ac}_3$ ), so that this region below the maximum of  $\text{Ar}_2$  or  $\text{Ar}_3$  apparently does not exist on cooling, an anomaly which cannot well be avoided on account of the experimental exigencies of the sample "catching up" with the furnace in temperature.

Regarding the location of  $\text{Ac}_3$  and  $\text{Ar}_3$ , the agreement, noted by Professor Carpenter as obtained both thermally by himself in association with Mr. Keeling and by crystallographic examination with Professor Stead, with the results of this paper, is particularly gratifying and convincing.

It is with regret that with many of Professor Benedicks's remarks the authors feel obliged to disagree most emphatically.

"The exuberant collection of curves" is apparently not sufficient evidence for him to discard the lone half dozen that their author, Professor Carpenter, now renounces, and on which slender scaffolding Professor Benedicks would still support an apparently inconsistent and unsound "theory" of allotropy. He also considers the



authors have "a certain disregard for theorizing." The authors do make a sharp distinction between hypothesis and theory and feel constrained to state that they do not consider the published ideas of Professor Benedicks on the allotropy of iron—in so far as they understand them—better than an untenable hypothesis or several such hypotheses, for it is difficult to reconcile with each other many of the statements made by Professor Benedicks in his several recent written contributions to the allotropy of iron. (See *Journal of the Iron and Steel Institute* for past two years.) The authors thoroughly agree with his statement "that our science, however, is a well-balanced equilibrium between laboratory work and pure brain work."

Professor Benedicks's latest criterion (§ 2 of his communication), based on his interpretation of the very interesting views of Professor Smits on allotropy, is that "*without exception, an allotropic transformation point is found at a higher temperature at heating than at cooling,*" and that therefore (§ 3), since "A2 is always found at exactly the same temperature, . . . A2 is not a chemical allotropic point (involving molecular change)." As stated by the authors on p. 2573, allotropy is a matter of definition. This one of Professor Benedicks would exclude all transformations reversible at constant temperature, including freezing and melting of crystalline substances.

Although their observations do not fully warrant the statement, nevertheless the authors are inclined to the belief, that at zero rate and for a mass approximating zero the temperature of Ar3 would equal that of Ac3, since with the smallest pieces Ac3-Ar3 is a minimum; therefore, granting this, by Benedicks's latest theory, iron would have no allotropic forms whatever. Professor Benedicks, however, does not make the converse statement, namely, when Ac is not equal to Ar, there is allotropy. Assuming this, it would follow that since  $Ac1 > Ar1$  for the Fe-C system, the pearlite point divides two "allotropic" forms.

Again, in § 2, Professor Benedicks would like to redraw the authors' Fig. 7, making in the limiting case, as above noted,  $Ac3 = Ar3$ . Therefore, by his own reasoning and analysis there is no allotropy associated with the A3 transformation. Professor Benedicks goes on to state that "as drawn, the straight lines signify the occurrence of a 'false equilibrium' of Duhem, which has not been definitely proved in a single case"; but this separation of the lines in Fig. 7 is the exact fulfillment of Benedicks's new criterion of the existence of "allotropy"; therefore A3 is an allotropic point by Benedicks's definition in the same § 2. This "Milo the Cretan" analysis might be

continued indefinitely in theorizing concerning Professor Benedicks's statements, but the authors will limit themselves to the ingenious hysteresis argument of Professor Benedicks, according to which, since with such "monumental" accuracy Ac2 is identical with Ar2, "immovable and enigmatic as a Sphinx," the point A2 has no existence because observed with samples heated in a furnace supplied with alternating current!

If the only thermal observations on the existence of A2 were those of the authors, this "theorizing" of Benedicks might possibly be considered as throwing doubt on the genuineness of the A2 point as here observed—not on its existence, but on its interpretation in terms of "allotropy." To refute Benedicks's argument here, it is only necessary to quote part of his § 4, "the cooling curves do not show any new facts, not known by the previous work of Osmond and others. The amount of heat connected with Ar2 seems to be little in comparison with that of Ar3, just as found by nearly all previous workers," etc. The presence of both Ac2 and Ar2 has been detected by many observers (see Tables I and II) using all kinds of furnaces, from the chimney of Professor Arnold and the electric heating by direct current of Mueller, Rosenhain, Carpenter, and many others, to the alternating-current heating of Rosenhain and Humfrey and the authors. The statement of Professor Benedicks in § 5 "that the failure of Professor Carpenter to find any Ac2 in his purest specimens, on which a very clear Ac2 is indicated on Plate VI, needs not to be caused by his method failing in accuracy, but might entirely be due to the absence in his work of the very serious source of error involved by the use of alternating current," is unwarranted by the facts. The Ac2 region *is present* in Professor Carpenter's curves, but, as stated on p. 2547 and accepted by him, "the poorer conductivity and the presence of gases in the wound-up sheets of otherwise untreated electrolytic iron producing a flattening out, distortion, and displacement of the critical regions, especially of the feeble A2."

Even if present only with alternate-current heating, A2 would still be a transformation in iron, allotropic or not according to the necessarily arbitrary definition adopted.

In order to convince even Professor Benedicks that the iron used by the authors has no Sphinx-like qualities at Ac2, due to an alternating-current heating supply, the authors have taken heating and cooling curves of a sample in an ordinary gas-heated muffle furnace, with the following results for A2 maxima (see also Fig. 9):

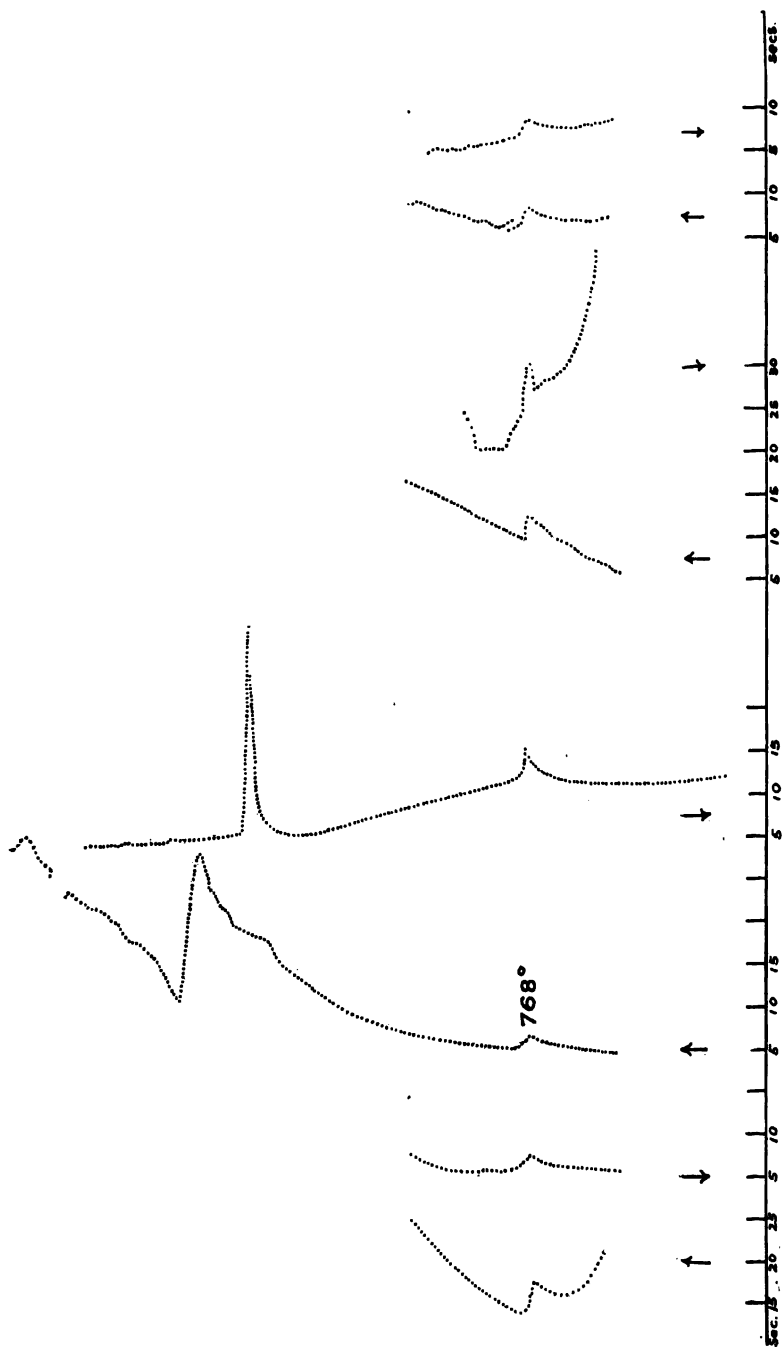


FIG. 9.—PURE IRON. INVERSE-RATE CURVES IN GAS FURNACE.

*Location of A2 of Iron in Gas Furnace.*

| Date.   | Sample. | Rate: Sec./Degree. |       | Ac2. | Ar2. |
|---------|---------|--------------------|-------|------|------|
|         |         | Up.                | Down. |      |      |
| 12-1-13 | F7      | 0.08               | 0.33  | 766  | 768  |
| 12-1-13 | F7      | 0.14               | 0.24  | 768  | 770  |
| 12-1-13 | F7      | 0.15               | 0.05  | 768  | 768  |
| 12-1-13 | F7      | 0.23               | 0.23  | 768  | 770  |

The authors object finally to Professor Benedicks unwarrantably classifying them in the ranks of the supporters of the "old allotropic views." They *observed* a reversible, thermal transformation at  $768^{\circ}$ , but it by no means follows that they necessarily believe in a  $\beta$  state.

In conclusion, the authors would suggest the following concerning the theory of allotropic of iron:

1. Some of the experimental facts that any theory must satisfactorily account for are: a definite thermal effect, independent of rate of heating or cooling, located at  $768 \pm 0.5 = \text{Ac2}$  identical with  $\text{Ar2}$ , i. e., with no measurable lag; a much greater thermal effect, but dependent upon rate, accompanying a marked crystallographic change, and, as extrapolated for zero rate, located at  $\text{Ac3} = 909$  and  $\text{Ar3} = 898$ . Both the  $\text{Ac2}$  and  $\text{Ac3}$  maxima appear to be anticipated by gradual changes in physical properties below these temperatures defining the maxima.  $\text{A2}$  and  $\text{A3}$  are distinct transformations.

2. Among the experimental uncertainties are, whether with  $\text{A2}$  there is associated any crystallographic change, however slight—it being recalled that the thermal change is also very slight; and whether there is any slight volume change accompanying  $\text{A2}$ . Concerning  $\text{A3}$ , we are not sure whether, as zero mass and zero rate are approached,  $\text{Ac3}$  exactly equals  $\text{Ar3}$  or not. For neither  $\text{A2}$  nor  $\text{A3}$  has the beginning of  $\text{Ac2}$  or  $\text{Ac3}$  been exactly located.

3. We may define an allotropic transformation in many ways. Confining ourselves to a pure substance in the solid state, let us make the simple definition: *an allotropic transformation is one accompanied by crystallographic change.*

4. There appears to be no doubt that  $\text{A3}$  is an allotropic transformation under this definition, whether or not for zero rate and mass  $\text{Ac3} = \text{Ar3}$ , so long as there is observed a crystallographic change. It is not necessary in the case of iron to add to the definition the complications of Smits's theory, actually observed with the masses hitherto used experimentally; namely, that  $\text{Ac3} > \text{Ar3}$ , and the faster the rate the greater the interval  $\text{Ac3}-\text{Ar3}$ .

5. Sufficient experimental evidence is yet wanting to decide in favor of A2 being an allotropic transformation according to the above definition.

6. So much for facts and theory. We still have the realms of analogy and hypothesis to work upon to guide us as to the probable nature of A2 in terms of allotropy. One of the greatest experimental difficulties encountered is due to the non-transparency of iron crystals rendering an adequate optical examination of iron passing through A2 well-nigh hopeless.

Turning to the transparent substance quartz, however, we have a material which appears to present a close analogy in certain of its transformations to those in iron. At  $575^{\circ}$  quartz has a very minute transformation, although a definitely defined one by thermal analysis, corresponding evidently to our A2 in iron. At about  $900^{\circ}$  there is a violent crystallographic change in quartz accompanied by a correspondingly large thermal effect and also by a very considerable volume change; in iron, exactly our A3. Now it is interesting to note that for the reversible point at  $575^{\circ}$  in the transparent quartz, there is a very slight crystallographic change accompanied by a minute volume effect, which anticipates the sharp maximum at  $575^{\circ}$  by many degrees in the same way that the numerous physical properties of iron appear to anticipate the sharp maximum of iron at  $Ac_2 = 768$ .

7. Reasoning from the quartz analogy, therefore, the following hypotheses may be made regarding the nature of the A2 transformation in iron: namely, that A2 is an allotropic point accompanied by a very minute but as yet undetected crystallographic change and differing from A3 mainly in magnitude; that when sufficiently exact expansion measurements are made on pure iron, a minute but abrupt volume change will probably be found at A2 preceded by a very feeble anticipatory region in the expansion curve below A2.

If experiment eventually proves the first of the above hypotheses incorrect, we have the oft-expressed alternative that the A2 transformation is mainly if not entirely associated with the passage from the ferro-magnetic to the para-magnetic state; and under the above definition, A2 would not be an allotropic transformation, and  $\beta$  iron would be really dead.

## The Influence of Various Elements on the Absorption of Carbon by Steel.

Discussion of the paper of Robert R. Abbott, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 82, October, 1913, pp. 2389 to 2400.

ALBERT SAUVEUR, Cambridge, Mass.:—Mr. Abbott has certainly made a strenuous effort to ascertain the influence of the various elements on the absorption of carbon by steel—a subject of great importance to those dealing with the case hardening of that metal. Because of the extensive and careful character of Mr. Abbott's experiments, one is all the more disappointed that his results, as he himself recognizes, are not more satisfactory; for, indeed they leave us just about where we were,—still entertaining uncertain views in regard to the carbon-absorbing power of various alloy steels. It might be asked whether Mr. Abbott's method of estimating the amount of carbon absorbed—namely, by weighing the specimens before and after the carburizing treatment—was the best one to select. Are not serious sources of error inherent to such procedure because of the difficulty of satisfactorily removing the carburizing material attached to the specimen? The method of least squares has certainly failed to solve the problem satisfactorily. By manipulating Mr. Abbott's results in a different manner I have obtained the following expression:

$$P = 100 - 50 C - 7 Ni + 20 Cr,$$

in which P represents the carbon-absorbing power; C, the percentage of carbon; Ni, that of nickel; and Cr, that of chromium. It is assumed that the carbon-absorbing power of pure iron, or what might be called its carburizability, is represented by 100. Applying the formula, for instance, to a steel containing 0.15 per cent. C, 3 per cent. nickel, and 0.50 per cent. chromium, its carbon-absorbing power would be

$$100 - 50 \times 0.15 - 7 \times 3 + 20 \times 0.50 = 81.50;$$

that is, 81.50 per cent. of the carbon-absorbing power of pure iron.

The formula was worked out by grouping together the carbon steels and figuring, roughly, the average retarding influence of carbon, which was found to be in the vicinity of 50 per cent. This, however, is true only of steels containing less than 0.50 per cent. carbon. In more highly carburized steels the retarding influence appears to be considerably greater. Similarly, the nickel steels contain-

ing nearly the same amount of carbon were examined and the retarding influence of nickel calculated, when it was found to be about 7 per cent. Finally, chromium, in a similar manner, was found to have a stimulating influence of 20 per cent. These values, however, can be only roughly approximate, because of the inconsistency of some of the figures. As a matter of fact, the results which appeared abnormally high or low were rejected. The formula, therefore, should be used cautiously if, indeed, it should be used at all. Were it possible to obtain accurate values for the influences of carbon, nickel, chromium, and other elements, a formula of the type here given would be of ready application and of great assistance.

DR. JOHN A. MATHEWS\*, Syracuse, N. Y. (communication to the Secretary†):—I have very little to offer in reference to this paper. It represents certainly a great deal of very careful work in the analysis and tests of specimens and confirms, I think, the general opinion as to the relative merits of different alloy steels in regard to the absorption of carbon.

In the paper given last year before the Mechanical Engineers by Mr. Lothrop, the same ratio was shown between the three types of steel: chrome-vanadium, carbon, and nickel. In that paper, however, this relation was indicated qualitatively and not quantitatively, as Mr. Abbott has attempted to do. Chromium steel shows the greatest tendency to absorb carbon, which I think is an advantage; that is, you can run your case hardening a little quicker with that class of steel. In chromium steels there is scarcely any tendency at all to the formation of lamellar pearlite, which is apt to remain after the steel is hardened. Of course, nickel and carbon steels with lamellar pearlite may be refined fairly well by a single quenching, and altogether if you give them a double quenching, but there are few plants that are regularly using the double quenching of case-hardened carbon or nickel steels; and there is a great deal of trouble in practice due to flaking, which follows either slag inclosures in the steel or the lamellar pearlite which has not been refined by a single quenching.

I wish Mr. Abbott would explain a little more clearly why he groups the steels in the way he does. He has several groups labeled nickel steel and several labeled chrome-nickel. It is not always plain on what he bases his division of the various steels into the groups that he gives.

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\* Non-member.

† Received Nov. 12, 1913.

The experimental data presented are of extreme value and very instructive to a great many people who are doing commercial case hardening. The value would have been fully as great had the mathematical part of the paper been omitted; yet I believe that if Mr. Abbott had been working with a definite series of experimental steels, made purposely of extreme uniformity and containing but one variable, he might have arrived at some formula which would define the influence of various elements in regard to the absorption of carbon. Making use of such a miscellaneous collection of alloy steels, furnished by different makers and manufactured by different processes, and far from uniform with respect to any one element in their composition, the results he has derived by his mathematical labors are of little value.

ROBERT R. ABBOTT, Cleveland, Ohio (communication to the Secretary \*):—Dr. Mathews inquires regarding the grouping of the different steels. Since the method of least squares does not give satisfactory results as applied to this problem, when more than three unknowns are present, it became necessary to group the different steels into classes of approximately the same per cent. of nickel and chromium so that in these different groups these two elements could be considered as constant, leaving two variables only with which to work—namely, carbon, and increased weight. For example, groups 6 and 9 are both labeled chrome-nickel. Group 6 contains those steels having a nickel content of from 4 to 4.5 per cent. and a chrome content of from 1 to 1.5 per cent., while in group 9 the nickel runs about 3 per cent. and the chrome about 0.5 per cent.

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\* Received Nov. 14, 1913.



## **Note on the Utilization of the Waste Heat of Regenerative Furnaces.**

Discussion of the paper of George C. Stone, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 82, October, 1913, pp. 2401 to 2402.

D. S. JACOBUS,\* New York, N. Y.:—The engineers of the country are waking up to the possibilities of waste-heat boilers. As the cost of fuel increases, and as more attention is given to economies, it is evident that a great deal may be gained by utilizing heat that has ordinarily been wasted. The art in the manufacture of waste-heat boilers has advanced so that it will now pay to install them under certain conditions where it would not have paid to install boilers constructed in accordance with older methods. In using boilers where the gases are at a comparatively low temperature, a great deal depends on the method of baffling the boiler in securing good results. The Babcock & Wilcox Co. has made a careful investigation of the laws of heat transfer and has applied the same to waste-heat boilers, which have been carefully tested under operating conditions, with the result that we now know what to expect with different arrangements of baffles and heating surfaces.

The old idea of installing waste-heat boilers was to provide an arrangement where the draft loss would be a minimum, and little or no attention was paid to the effect of different systems of baffling on the steaming capacity of the boiler. In some instances, to secure a minimum draft loss no baffles were placed in the boilers. After making a most careful study of the subject it developed that this practice was bad, and that to obtain the best commercial economy, in place of endeavoring to obtain a minimum draft loss, an arrangement should be used that would lead to the maximum amount of heat transmission with a comparatively high draft loss. In nearly every case the amount of resistance of the gases passing through the boiler involves the use of an induced-draft fan, but the additional capacity developed by the boiler over that which could be secured with the older designs, through arranging the heating surface properly and using proper baffles, much more than pays for the increase in the steam required to drive the fan.

In the older practice with gases at, say, 1,100° or 1,200° F., about 18 or 20 sq. ft. of heating surface would be allowed for each boiler horse power developed. By our present methods it is perfectly feasi-

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\* Non-member.

ble to develop a boiler horse power with 10 or 12 sq. ft. of heating surface for this gas temperature.

The introduction of an induced-draft fan outfit has been found an advantage in some instances where waste-heat boilers have been applied, as it allows better regulation of the draft acting on the furnace, with the result that the output of the furnace has been increased over what it was with natural draft. There were therefore two gains through installing the waste-heat boiler, one through increasing the capacity of the furnace on which the boiler was applied, and another through utilizing the waste heat.

E. B. CARTER,\* Philadelphia, Pa.:—Two points of the subject that do not seem to have been touched are very important to persons considering it. These are, the question of first cost, and the question of cost of horse power development. Naturally the cost of horse power installed runs very much higher than the cost of installing the same horse power in the boiler house, because you have to have the auxiliaries and the small units. In the cost of operation you have additional costs in nearly every item except the cost of fuel, and I would like to inquire of Dr. Jacobus whether they have obtained any data on those subjects. I also understand that from experiments they have made it has not paid to install boilers where the temperatures were much below 500° C.

T. T. READ, New York, N. Y.:—It may be of interest to call attention to the fact that the use of waste-heat boilers has become general practice in the reverberatory smelting of copper ores. At the Steptoe Valley smelter they have a number of oil-fired reverberatory furnaces, and S. S. Sörenson, the Superintendent, has made a series of interesting comparisons between the results with the Sterling type of boiler and the Babcock & Wilcox boiler. As his paper, which has just appeared, is the first comparison of that sort that has come to my attention, it may be well worth while to cite a few figures from it. At the Steptoe plant the Sterling boilers were the first used, and the management was prejudiced in favor of them because of their being so easily cleaned. Later they installed some Babcock & Wilcox boilers and carried out a series of comparative tests, of which Mr. Sörenson has given us the record. The Sterling boiler was of the ordinary type of that make; the Babcock & Wilcox was a special type, especially designed for the Steptoe Valley company. The boiler horse power of the Babcock & Wilcox installation was 520 and

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\* Non-member.

of the Sterling 375. In a 100-day test the Babcock & Wilcox made a net recovery of \$25,000 worth of oil and the Sterling boilers recovered \$20,000 worth. Mr. Sörenson's conclusions are given at length in his paper,<sup>1</sup> but may be summarized by saying that the tubes in the Babcock & Wilcox boiler are so arranged as to give greater heat efficiency; and the greater cost for cleaning and repairs is overcome by the greater recovery of heat.

On the question of first cost I might say that at the Copper Queen smelter, at Douglas, Ariz., Erie boilers were installed because of their lower first cost. I have been told that the results show that the efficiency of these boilers is comparatively high, but difficulty is experienced on account of the priming to which the Erie boilers are subject. Waste-heat boilers are typically driven at overload, and under such conditions I understand that the Erie boiler primes badly. It is evident from this that it is well worth while to devote some study to the selection of the proper type of boiler for waste-heat recovery before beginning the construction of a plant.

JOSEPH W. RICHARDS, South Bethlehem, Pa.:—I wish to comment on the inefficiency of the chimney. If you are using a chimney merely to produce draft, you are using one of the most inefficient apparatus that has ever been devised by man. The mechanical efficiency of the chimney for producing draft, calculated upon the heat energy which goes into it, is certainly less than 1 per cent. Now consider most of our regenerative furnaces, which are supposed to save a great deal of the heat from going into the chimney, and yet about 25 per cent. of all the heat that the coal furnishes goes up the chimney. We are using then this 25 per cent. of the calorific power of the coal at an efficiency of less than 1 per cent., if we are utilizing the chimney as a draft producer. In the best regenerative steel furnaces about 25 per cent. of the heating power of the fuel goes into the steel; so you are using up as much heat to run the chimney as you get efficiently into the steel, and that chimney heat is utilized to produce draft at an efficiency of less than 1 per cent. This points to the general conclusion that in every case where it is possible to use the heat that is going to the chimney for any other purpose whatever it should be thus used, and the function of the chimney as a draft producer replaced by the fan. If you can thus reduce the temperature of the gases down even to the ordinary temperature, so much the better.

I think that the apparatus under discussion could well be provided

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<sup>1</sup> *Mining and Scientific Press*, vol. cvii., No 15, p. 576 (Oct. 11, 1913).

with feed-water heaters, and thus reduce the temperature of the gases still lower, and replace still further the energy required by the chimney by the mechanical draft. You have at least 99 per cent. of the heat energy in the gas absolutely wasted when you are using the chimney simply as a draft producer.

D. S. JACOBUS:—The first cost of the boilers is greatly reduced through our present practice as compared with the old, as by arranging the boiler and baffles properly a much greater capacity is obtained for a given amount of surface than was possible with the older designs. Whether it will pay to install waste-heat boilers at temperatures lower than  $500^{\circ}\text{C}$ ., or somewhat over  $900^{\circ}\text{F}$ ., depends on the volume of gas involved. We are installing boilers to run with this temperature of gases where there will be a large return as compared with the capital invested. How much lower temperatures we can handle depends on the individual case at hand, and cannot be stated unless all of the conditions are considered.

There is another feature that was brought up by Professor Richards, namely, that a feed-water heater or economizer might be used to advantage in connection with a waste-heat boiler. An economizer in certain instances would give a material increase in the efficiency, but the economizer problem in connection with a waste-heat boiler is a difficult one, because usually there are times when a large volume of the gases passes through the boiler at a much lower temperature than the average. When this occurs the amount of heat absorbed by the economizer as compared with that absorbed by the boiler increases, with the result that steam may be generated in the economizer. To avoid this it is necessary to employ some sort of an automatic controlling device.

A MEMBER:—Will Mr. Jacobus tell us about how cool it is possible to make the gases as they leave the boiler?

D. S. JACOBUS:—The temperature of the gases leaving the boiler depends upon the arrangement of the boiler surface and baffles, and, in general, the higher the draft resistance the lower will be the final temperature of the gases for a given initial temperature and volume of gases. This temperature may be, say,  $500^{\circ}\text{F}$ ., all depending on the particular arrangement which is used, the best arrangement, of course, depending on the conditions existing at the plant. There are so many features to the problem that it is hard to generalize. Increasing the velocity of the gases over the heating surface increases

the heat-transfer rate, and with our present practice the heat-transfer rate is about twice what it was for our older practice. This does not mean that in applying a boiler to a furnace we would necessarily secure double the capacity that we would by our older practice, as there is a given amount of heat in the gases leaving the furnace, and doubling the heat-transfer rate does not therefore double the boiler capacity.

JOSEPH HARTSHORNE, Pottstown, Pa.:—I think that Professor Richards has been rather liberal to the chimney. From my own observation and experience, I can say that I think that it will be generally found that the chimney loss of heat will be much nearer 30 per cent. than 25 per cent.

I recently had occasion to make a rough estimate of the amount of heat which would be available for steam from the flue gases of a 50-ton open-hearth furnace. The data, partly assumed, were as follows: 50-ton heats, taking 10 hr. to finish; 500 lb. of coal, having 14,000 B.t.u. per pound, per ton of steel; stack loss, 80 per cent.; temperature of flue gases, 1,200° F.; and temperature of gases leaving the boiler, 600° F. On this basis, there would be, in round numbers, about 50,000,000 B.t.u. available for making steam during the 10 hr. This shows what can be expected, as far as quantity of heat is concerned.

As to practicability, it is well known that the process is being used in this country, fans being used to draw the waste gases through the boilers. In 1912 I saw it successfully in use at Phoenix-Ruhrort, on two 40-ton furnaces. There was a 200-h.p. water-tube boiler attached to each furnace, to which the waste gases came at a temperature of about 700° C. There was a stack, about 20 ft. high, beyond each boiler, into which a pressure fan blew a stream of air, drawing the gases through the boiler on the ejector principle. The fan was driven by an 80-h.p. motor, which seems an excessive power requirement. The boilers were said to evaporate 22 liters of water per square meter of heating surface (0.54 gal. per square foot).

Drawing the gases through the boiler by means of a fan would appear to be the more economical and efficient method. The gases should be reduced to at least 400° F., which should not be injurious to the fan.

An added advantage is the fact that the furnaces should be more easily controlled by the damper, atmospheric influences being entirely eliminated.

G. C. STONE:—As to our boilers, the cost of installation is very small. The cost of boiler per horse power is large, as it is necessary to have a large heating surface. Our cost of attendance is extremely small; as our boilers are placed, they are in widely separated parts of the plant and we take more than we should, but the actual labor would be about one man to ten boilers. The repairs to the boilers have been slight and the cost of cleaning has been very small. We are actually running with the gas, as I said, at  $450^{\circ}\text{C}$ ., which is about  $840^{\circ}\text{F}$ ., and at times it is as low as  $300^{\circ}\text{C}$ . It would not pay to put in boilers if the gases were regularly at that temperature.

## **The Scoria Process for the Manufacture of Fine-Ore Briquettes, Flue-Dust Briquettes, and Slag Brick for Building Purposes.**

Discussion of the paper of Ernest Stütz, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 79, July, 1913, pp. 1257 to 1265.

H. O. HOFMAN, Boston, Mass.:—I have hunted in vain for a figure which gives a dehydration temperature of cement. I was wondering if Mr. Stütz had a figure of that kind.

E. STÜTZ:—No, I am afraid I have not.

H. O. HOFMAN:—I believe some figures have been published that cement disintegrates at 400° or 500° C. It seems to me a very low temperature. Mr. Stütz just made the statement that the disintegration of this briquette begins at the temperature at which the briquette begins to sinter.

E. STÜTZ:—Above the sintering point.

H. O. HOFMAN:—The sintering point would be about 1,200° C.

E. STÜTZ:—Yes, roughly speaking. I am afraid I have no information about the exact degree of dehydration.

H. O. HOFMAN:—I have looked a great deal for such a figure and I have not been able to obtain it. Professor Howe says I might have tried myself. But my interests were directed in another line; although that is, perhaps, a good suggestion.

CHAIRMAN RICHARDS:—Is not Portland cement sometimes used for the test in a cupellation furnace and a drying-out furnace?

H. O. HOFMAN:—Yes, it is used, but that is a higher temperature, of course. But I have been trying to get a figure as to where it loses all its water. I understand it begins to lose water at 500° C. But there are different silicates or hydrosilicates in the cement, so that one would have four or five or six figures to show the different stages at which the cement loses its water.

CHAIRMAN RICHARDS:—I would ask whether the use of this material in blast furnaces has shown increased capacity of furnace or decreased consumption of fuel.

E. STÜTZ:—It has shown decreased consumption of fuel. With 43 per cent. (calculated on the burden plus limestone) addition in the shape of Scoria briquettes furnace operation was absolutely regular. I have no definite figures on coke consumption.

FELIX A. VOGEL, New York, N. Y.:—I want to call attention to the statement of costs published by Mr. Stütz in his paper, which was taken from an article published by Dr. Weiskopf some time ago. In this article the cost of production by the Scoria process is given as 32 c., while by Dr. Schumacher's process it is given as 41 c. I would like very much to know whether the 32 c. represents the actual cost as obtained in every-day practice. We have a plant in Austria, producing 200 tons daily, which actually makes briquettes for 25 c. in American money per ton, besides two plants in Germany which are operated for less than 30 c., including amortization. The figure given by Dr. Weiskopf of 41 c. was obtained, not from an operating plant, but from the estimated operating cost of a one-press plant furnished by the press manufacturers, and this cost is very conservative and away within actual operating costs. At a plant at the works of the Lackawanna Steel Co., which is an experimental plant only, and where no labor-saving devices have been provided for briquette handling, and where the flue dust is screened very roughly through a grizzly at considerable expense, the actual operating cost has been around 59 c. for several months.

It would be very interesting to find out whether the Scoria process can actually make briquettes for 32 c., in view of the fact that the process is much more complicated than is the Schumacher process, in which either pickling liquor or a cheap sulphate of iron is the only substance added to the dust, whereas in the Scoria process some 8 to 10 per cent. of slag must be added, and the slag must be ground to the fineness of cement.

E. STÜTZ:—The figures in my paper were taken from *Stahl und Eisen* and translated into dollars and cents and pounds. As those given in *Stahl und Eisen* were not questioned at the meeting of the Verein deutscher Hüttenleute, where they were presented, there was no need for me to inquire into their origin. I have no operating figures of a plant in the United States. In regard to the expense of preparing the slag, certainly slag has to be taken in the granular state, but the grinding is not a very expensive process. Of course, the material is first hydrated, and in that way is made very soft, and the grinding is more of a grinding and mixing operation.

FELIX A. VOGEL:—As far as the hydration of slag is concerned, there seems to be little foundation for the claims made. After the so-called hydration, which purposes in itself a disassociation of the slag into minute particles, the slag must yet be ground in Chilean mills. The claim of the Scoria patent, as we understand it, is that



the slag, when it is submitted to superheated steam, will hydrate, and, furthermore, disintegrate. This, however, does not seem to be the case, necessitating a second operation. You have then two operations: the first one, of submitting granulated slag to superheated steam in mixing apparatus, and the second one, of subsequently grinding the hydrated slag in Chilean mills.

Dr. Schumacher controls a process which is quite similar to the Scoria process. However, the slag is ground fine without preliminary hydration in steam cylinders, the briquettes being hardened under steam pressure only. This process, using only 3 to 4 per cent. of slag and about 0.5 per cent. of lime, is much simpler than the Scoria process, which uses from 8 to 10 per cent. of slag.

E. STÜTZ:—In regard to Mr. Vogel's statement that there is nothing in hydrating, I think there is a great deal in hydrating as a suitable preparation of the binder. By it the briquettes are made extremely porous, and while the binder is hydraulic during its passage through the top gases it is turned into a fusion binder in the hearth. I do not know what objections Mr. Schumacher found to the process, but it is in use and those are the advantages claimed for it.

FELIX A. VOGEL:—I understand there are two plants using the Scoria process in Germany at present, neither of which has shown the operating costs here published.

F. L. GRAMMER, Leesburg, Va. (communication to the Secretary\*):—The table offered by E. Stütz of the various agglomerating devices is interesting, but there are influencing factors in selecting a process not there exhibited; for example, the great purity of the Gröndal brick.

It is, however, in Dr. Weiskopf's citation that furnacemen will find valuable thought. Most of us have felt that blast pressure regardless of volume influenced reduction of ores and combustion of fuel. It is true that the best fuel records are found in the charcoal furnaces of Europe, where rich uniform ores are used and a metal of very low silicon is made, and such furnaces exhibit low blast pressure. It is, however, to the ore richness, fine crushing (1 to 1.5 in.), acid slag, low silicon in metal, and absence of sulphur in ore that we have usually given the credit for low fuel consumption.

If two-thirds of the gas produced in high-pressure blast-furnace plants goes to boilers, certainly much less would be required where

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\* Received Aug. 9, 1913.

the blast pressure is 7 lb. than where it is 17 lb. It is only by the greatest plant economies in the use of steam that these pressures were overcome without turning the furnace into a gas producer by lightening the burden to make a richer gas fuel.

In a paper presented at the New York meeting of the Institute in October, 1903, I cite<sup>1</sup> 20 to 30 cu. ft. of furnace space per ton of iron per 24 hr.; this was under the conditions of high pressure of blast and great velocity. The fuel consumptions were not such as to excite remark either way.

If with low pressure and slow driving and the consequent fuel economy such outputs as 1 ton per 35 cu. ft. are obtained, the matter is of great interest.

ERNEST STÜTZ, New York, N. Y. (communication to the Secretary\*):—In further reply to Professor Hofman's question regarding hydration temperature of cement, I have consulted Professor Mathesius and am advised that according to previous publications the loss of water begins at 500° C. and increases up to 1,100° to 1,200° C. As far as known, it has not been possible to determine the presence of definite hydrates which are decomposed at fixed limits of temperature.

Some practical experience has been derived, however, from the manufacture of so called Dinas stones from ground quartz with an addition of from 3 to 4 per cent. of caustic lime. Pressed into brick shape, these are hardened in cylinders similar to those used in the Scoria process. Also German sand-lime bricks are made in a similar manner but with a considerably larger addition of lime. In the subsequent burning process of the Dinas stones it was found that between 1,100° and nearly 1,500° C. these stones are excessively sensitive to shocks or loads. In the kilns it is therefore impossible to place more than two or at the outside three layers on top of one another, because otherwise the bottom bricks are crushed in the course of the burning operations.

The sintering process between lime and quartz begins to bind only after heating in a very careful manner to nearly 1,500° C. and gives the Dinas stones their well-known solidity. Precisely the same observation can be made with ore briquettes composed of lime and iron oxide or cement and iron oxide. The hydrating binder is destroyed at a temperature between 1,000° and 1,100° C. and the sintering binder becomes active only at higher temperatures, so that the destruction of such briquettes is liable to occur in the blast furnace.

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<sup>1</sup> *Trans.*, xxxiv, 616 (1903).

\* Received Nov. 29, 1913.

The special advantage of the Scoria process lies in the fact that with blast-furnace cinder, sintering as it does between  $1,050^{\circ}$  and  $1,100^{\circ}$  C., the hydrosilicates are destroyed only after the sinter binding has begun to be operative. For that reason, as the operation of the process during a number of years has proved, the Scoria briquettes maintain their lumpy consistency up to the melting zone.

Mr. Lee's paper is highly interesting, as it brings out the point that a saving in coke cannot be claimed for operation with nodulized material.

Permission to publish the coke consumption of German furnaces running on briquettes is unfortunately not obtainable, but it is certainly equal to the best published performances of American furnaces running on good lumpy ores for Bessemer iron.

Another interesting statement of Mr. Lee's concerns the  $\text{CO}_2$ : CO proportion as being between 1: 1.8 and 1: 2.5 for gas-reduced ores (which is in accordance with German experience), while with ores hard to reduce the proportion is only from 1: 4 to 1: 6. In the latter case it seems safe to assume that coke consumption will be still above Mr. Lee's figures of 2,300 to 2,400 lb. per ton of iron.

Assuming a cost of nodulizing about equal to that in Germany (from 75 c. to \$1 per ton) with no resulting saving of coke, it appears that these costs are not counterbalanced by any advantages in furnace operation. With Scoria briquettes these conditions are, however, greatly improved and coke consumption is sensibly reduced, completely offsetting any greater cost of installation.

Mr. Vogel's discussion adds little to the general knowledge of the subject of briquetting. It is true that Scoria boasts so far of only two installations, but these are in operation with two of the admittedly most up-to-date German metallurgical establishments, Krupp and Thyssen. Both closely investigated all other methods, including Dr. Schumacher's, and after investigation and trial preferred Scoria. They found that the process did not confine itself only to the briquetting of flue dust, that the solidity of the briquettes did not vary from day to day according to differences in operating conditions, and that it could be used for fine ores together with flue dust or without it.

At the Thyssen plant it was found by lengthy experiments that the Scoria process alone among all others was able to make solid briquettes of the fine Norwegian concentrates (ground to an average diameter of 0.1 mm.) so as to be reducible in the top gases; thereby reducing coke consumption. Even the Gröndal process was not able to make briquettes of sufficient hardness with this material.

## Shock Tests of Cast Steel.

Discussion of the paper of John H. Hall, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 79, July, 1913, pp. 1247 to 1256.

WILLIAM R. WEBSTER, Philadelphia, Pa.:—I would like to call attention to the fact that the results of the ordinary tension and bend tests do not always give us the information we want even if we figure out the amount of work done. You want a bending test of sufficient width and full thickness. In the case of eyebars, for instance, I have had experience with a 10- by 1-in. eyebar which gave perfectly good results in a full-size test of the finished bar. The 10- by 1.5-in. and 10- by 1.75-in. eyebars from the same heats of steel were absolutely worthless in full-size tests. The narrow bending tests from all these bars gave good results. But after going into the matter fully, we found that if pieces about 3 in. wide and full thickness were used for the cold bending tests, the heavier material would not stand this test, but failed. That is, in order to check the quality of the rolled bar you should have a wide piece of full thickness for cold bending, as the narrow pieces give misleading results.

J. E. JOHNSON, JR., New York, N. Y.:—I would like to ask if there have been any tests made to compare the results of Charpy tests with the true dynamic test similar to the Wohler test, except that the piece is subjected to a tensile or compressive stress and to alternating stresses in addition, at the same time. This seems to me to approach more nearly than any other test to the conditions of actual service where the piece is under a fixed initial stress plus a highly variable and often alternating stress. Some tests were made on this plan in England within a year or two. The test piece was subjected to either a tensile or compressive stress of known amount and simultaneously to alternating stresses in addition. Such a test as this gives information which we cannot get by a tensile test or even from the tensile strength multiplied by an elongation. Such tests, however, are exceedingly tedious and require long periods of time in order to obtain valuable results. If material could be subjected to these dynamic tests and the same material to the Charpy shock test, and if some reasonable qualitative relation could be established between the results of the two tests, then we could assume that the shock test, which is so simple and easy to make, was a measurably accurate test of the dynamic qualities of the material. At present it does not seem

to me that we have any adequate ground for assuming this to be the case, though I do not by any means wish to intimate that it is not. I would like to know if these gentlemen who are familiar with this subject know whether anything has been done along this line.

BRADLEY STOUGHTON, New York, N. Y.:—I would like to say a word further as to the value of the shock test. I have used it in two separate ways. About two years ago I had occasion to measure the strength of gear teeth under shock. The usual way is to raise a heavy weight and allow it to fall on a tooth and see if it breaks the tooth off. If it does not break it off the first time, one allows it to fall again, and, after a certain number of blows, the tooth breaks. In some cases it is even more crude than that; a man taking a sledgehammer and hammering on the point of a tooth until he breaks it. These seem to be the accepted forms of testing the strength of gear teeth. So a couple of years ago, having this problem under consideration, I made a special form of test piece and rigged up a special form of Frémont machine to break the teeth off at the base and measure the residual force left in the falling weight. We never got beyond a first investigation, which I think gave us some data to show that it did give an indication of the strength of the tooth in service. But I am hoping that the work may be continued.

More recently Professor Campbell, of Columbia, has made some Frémont shock tests for me on some steel castings and there we had a very remarkable result in one respect. The castings, which, under the tensile test, appeared to be excellent, and did not disclose any evidence of overheating in the tensile strength fracture, when tested in the Frémont machine gave almost no resistance to shock. Furthermore, the fracture was as coarse looking as if the castings had been badly overheated. Certainly those castings were not what they should have been, and yet the tensile test did not give us any indication of their dangerous character. Perhaps Professor Campbell would be willing to say something more about that.

WILLIAM CAMPBELL, New York, N. Y.:—I think one of the main objections to the shock test is because material that is thought to be very good often appears to be very bad under shock. The steels that Mr. Stoughton sent me, six different samples, were apparently very good, and I expected to get fairly decent readings on all of them; but three of the samples were so brittle that they broke almost like sugar would break. The fracture was absolutely different from the fracture you get under the tensile machine. And on cutting these

samples up and examining them under the microscope we readily found out what the trouble was. The microstructure was absolutely different from that of good material. It seems that the impurities, manganese, sulphide, slag, etc., had arranged themselves around the austenite grain during solidification, and under this form of test the weakness from such a structure is immediately shown up, whereas frequently it is not at all patent when we take the results from the ordinary tensile test piece. One objection to the drop testing machine of the Frémont type is the fact that it has to be calibrated pretty frequently. It appears that the springs vary somewhat, and the original calibrated card that is supplied with the machine does not remain accurate very long; but from the fact that the machine can be so very easily re-calibrated that feature does not seem to take much from its value.

K. W. ZIMMERSCHIED, Detroit, Mich.:—The remarks of Professor Campbell seem to have a strong bearing upon a new conception of the structure of steel, which is gaining a number of adherents. Lately there has been a good deal written about the greater strength of the intercrystalline material in a piece of steel than that of the intracrystalline part; that is, it is held that the crystals themselves are weaker than the amorphous material which lies between them. If this is the case, the more intercrystalline material there is present, the stronger will be the structure as a whole. Now when Professor Campbell shows that his sample, which broke under shock with very little resistance to fracture, contained a considerable amount of impurities around the grains, it may be argued that this weakness is due more to the lack of strong intercrystalline material than to any inherently greater weakness of the crystals themselves.

WILLIAM R. WEBSTER, Philadelphia, Pa.:—J. E. Stead, in discussing C. H. Ridsdale's paper on The Correct Treatment of Steel—read before the Iron and Steel Institute of Great Britain in 1901—gives a very good explanation of why steel that had given satisfactory results in the tension tests sometimes breaks unexpectedly under shock. He said:

“The author had pointed out the bearing the dimensions of the crystalline grain had upon the strength. In the tension testing-machine, they did not get much difference between a coarse-grained and a fine-grained crystalline steel when the strain was gradually applied; but under a falling weight the difference was most marked, and often the coarse-grained steel would snap like a carrot. Such

fractures were not due to intergranular deposits, but to true separation of the cleavage planes. The large crystal masses present large planes of weakness, and when a strain was brought to bear upon these crystals, they separated through their mass, and once the cleavage was started, it rapidly traveled from crystal to crystal through the whole section of the steel. When he was studying, many years ago, the crystalline structure of steel, he obtained very coarse crystalline steel, which elongated 30 per cent. in the testing machine, and yet when a small section was placed upon a V block, and a sudden blow was given so as to put the under surface in sudden tension, on examining the piece under the microscope, he found that one or two of the crystals in the centre of the piece in which the cleavages happened to be vertical or at right angles to the surface had fractured."

ALBERT SAUVEUR, Cambridge, Mass.:—I am glad to see Mr. Hall call attention to the usefulness of the shock tests for detecting that kind of brittleness existing in certain steels, which is not readily detected by the tensile test. I agree with him that shock tests are not used in this country as frequently as they should be. When in France, I visited a number of industrial laboratories and was impressed by the very general use of the shock tests and the excellent results they yielded. The close relation existing in castings between coarseness of structure and brittleness under shock is well brought out by Mr. Hall, as is also the strengthening influence of quenching very mild steel and the value of such treatment in increasing its resistance to shock.

HUGH P. TIEMANN, Pittsburg, Pa. (communication to the Secretary\*):—Mr. Stoughton referred to insolated coarse crystals frequently found in large castings after annealing, and remarked that it would be of interest to have this subject investigated and its cause determined.

This is one of the effects of mass which is principally mechanical in its nature and perhaps for this reason has apparently received little attention; at least, judging by what has been published.

The structure of castings is greatly influenced by the rate of cooling, which with those of large size is extremely slow, due to the large mass itself, and materially assisted by the refractory (non-conducting) nature of the molds in which they are generally cast. The cooling is also retarded by increasing the initial (pouring) temperature, particu-

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\* Received Nov. 14, 1913.

larly during the critical period when crystallization occurs, since there is more heat to be dissipated and the interior of the mold is brought to a higher temperature.

Under these conditions the crystals may be  $\frac{3}{8}$  to  $\frac{1}{2}$  in or even larger across, which renders a casting unable to withstand any violent shocks or stresses to which a roll, for example, is subjected. Cases have come to the writer's attention where a handful of loose crystals could be secured by striking a casting a single blow with a light hammer. Such a casting was composed of coarse crystals throughout, either because it had escaped annealing through some accident, or because of excessive shrinkage strains during the initial cooling, to which reference is made later. "Ingotism" is the term which Howe has applied to this condition. To secure a durable casting, the crystals must be refined, usually by annealing. This consists in extremely slow heating to a temperature somewhat above the critical point ( $Ac_3$ ), at which the object is held for some time, and then slowly cooled.

Where there is no danger of setting up cracks or excessive strains, which is generally only true of relatively small pieces with simple sections, a finer structure can be secured by quenching in water or oil than by simple annealing, this latter treatment or a partial reheating (tempering) being subsequently employed to remove as far as possible any strains or brittleness, and thereby render the material tougher because more ductile.

By either of these methods of treatment, even where repeated, there will almost invariably remain in castings of any considerable size some large isolated crystals, which stand out prominently in the surface of a fracture, being capable apparently of resisting any purely thermal treatment, and surrounded by fine-grained material resulting from the given treatment. Forging or rolling (mechanical working) at the relatively high temperature customary for these operations is the only method by which such crystals can be broken up and refined.

Such a condition is commonly explained as due to too high a pouring temperature producing coarse crystals which cannot be refined by heat treatment alone. This partial explanation is not restricted to ordinary workmen who are accustomed to observe an effect without studying the cause, but is also given by those whose training would naturally be supposed to lead them to study why such a condition should bring about this result.

A microscopic examination will show that the structure of the isolated crystals in a carefully annealed casting is the same as that of the surrounding fine-grained material, hence it is not a case where it



is impossible for the effect of the heat treatment to penetrate to all parts alike.

A casual examination will usually be sufficient to show that these isolated crystals may be actually separated in places from the surrounding mass, and the writer has found in some cases that the space was sufficient to permit the insertion of a penknife blade or other slender object to a depth of  $\frac{1}{4}$  in. or even more. In other words, we are here concerned, not with one continuous mass, but with several more or less separate and distinct entities, and it would be as reasonable to expect two pieces of steel, one simply laid in imperfect contact with the other, to be united together by simple heating, as for these crystals to become incorporated with the surrounding mass by this treatment. Since oxidation is absent, forging or rolling will weld these surfaces together, as has been shown by Stead in the case of sufficiently deep-seated blow-holes.

The separation of the crystals is evidently due to the contraction after solidification, which is a different condition from that causing a pipe or other contraction cavity produced practically entirely during, and not after, solidification. Upon solidification the original external dimensions of a casting are determined by the internal dimensions of the mold, its subsequent contraction being progressively resisted by successive interior layers which are at a higher temperature. These interior layers will then continue to contract after the contraction of the exterior layers has practically ceased, and the strains thus set up may be sufficient, under extreme conditions, to bring about actual breaks in the continuity, whereupon the stresses at these places will fall. Where the strains have been insufficient to cause actual separation, suitable heat treatment will have a refining effect on the entire structure, unless perhaps where they are very great. This same condition is probably largely responsible for the brittle and crumbly condition of overheated (not burnt) steel.

WILLIAM C. CHANCELLOR, Pittsburg, Pa. (communication to the Secretary \*):—In practice, it is usually the case that shock tests, fatigue tests, etc., are regarded as superfluous and belonging to the theoretical side of metallurgy. While bringing out the extreme sensitiveness of the Frémont test, Mr. Hall, in his paper, Shock Tests of Cast Steel, shows in a very conclusive way that tests of this sort yield practical information on the behavior of steels which is more vital, possibly, than the information obtained by the usual tensile tests.

I have had occasion to make some very simple shock tests, and the

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\* Received Sept. 10, 1913.

results are given here to further bring out the practical and useful nature of this class of test in cases where the usual tensile methods furnish little or no idea of the relative quality of steels. Unfortunately, these tests are not comparable with any other tests. The method is very crude, having no means of measuring the residual energy of the final blow. The test piece is a round bar, 0.75 in. in diameter and 12 in. long. It is notched with a cutter having a guard which prevents the notch from being over  $\frac{3}{8}$  in. in depth. The test piece is held firmly in the machine by wedges and the blows are struck by a weight of 56 lb. falling 1 ft. The striking part of the weight is equipped with a knife edge. Even under these unfavorable conditions it is evident, from the following data, that the drop test throws a very important light on the behavior of cast steel, and that the results are much more conclusive and consistent than the results of the tensile tests.

In the first set are given the results of annealing mild cast steel at various temperatures. The figures for the drop test are the average of at least two tests, while the tensile tests are the results of one bar annealed at each temperature. This was thought sufficient on account of the slight variation in strength for a considerable variation in temperature. All specimens were from the same grade of steel and annealed under the same conditions except temperature.

Theoretically, the correct annealing temperature for this grade of steel is 875° C., and the results should be higher as the temperature increases up to this point and then fall off as the temperature rises from 875° to 1,200° C. In neither the drop nor the tensile tests is this strictly the case, as there are some variations in both, but much more in the latter than in the former.

| Annealing<br>Temperature.<br>Degrees C. | Tensile Tests.                       |                                          |                                         |                                    | Drop Tests.      |                    |
|-----------------------------------------|--------------------------------------|------------------------------------------|-----------------------------------------|------------------------------------|------------------|--------------------|
|                                         | Elastic<br>Limit.<br>Lb. per Sq. In. | Ultimate<br>Strength.<br>Lb. per Sq. In. | Elongation in<br>2 Inches.<br>Per Cent. | Reduction<br>of Area.<br>Per Cent. | Foot-<br>Pounds. | Breaking<br>Angle. |
| As cast.....                            | 32,700                               | 67,000                                   | 21.0                                    | 22.3                               | 170              | 4.0                |
| 750                                     | 35,400                               | 65,300                                   | 26.5                                    | 29.7                               | 280              | 8.5                |
| 800                                     | 38,800                               | 75,600                                   | 21.5                                    | 24.4                               | 390              | 9.0                |
| 850                                     | 44,500                               | 72,600                                   | 22.0                                    | 28.1                               | 340              | 7.0                |
| 900                                     | 40,800                               | 74,500                                   | 28.5                                    | 40.8                               | 670              | 19.5               |
| 950                                     | 41,500                               | 79,100                                   | 30.5                                    | 44.6                               | 450              | 15.0               |
| 1,000                                   | 41,500                               | 79,700                                   | 33.8                                    | 56.0                               | 560              | 15.0               |
| 1,100                                   | 39,300                               | 76,900                                   | 25.0                                    | 33.1                               | 450              | 12.0               |
| 1,200                                   | 39,500                               | 69,700                                   | 26.5                                    | 37.0                               | 450              | 15.0               |

The main point brought out by the comparison is that while the tensile tests show only an indifferent change in strength for a consid-

erable change in temperature, the drop tests show a radical change for each change in temperature. The highest ultimate strength, 79,700 lb. per square inch, is only 19 per cent. greater than the strength of the unannealed steel, 67,000 lb. per square inch, while the greatest resistance to shock, 670 ft.-lb., is 293 per cent. greater than the unannealed steel, 170 ft.-lb.

The superior value of the drop test in detecting the relative quality of steels which show similar tensile results is again brought out in the following tests to determine the effects of oxidation on the steel as manufactured in the open-hearth furnace.

A series of heats, made with no special precautions against oxidation, gave the following results:

|                                       |        |
|---------------------------------------|--------|
| Tensile strength, lb. per sq. in..... | 72,000 |
| Elastic limit, lb. per sq. in.....    | 34,000 |
| Drop test, foot-pounds.....           | 429    |

A second series of heats were made, using special precautions against oxidation in melting and working the heats. These gave the following results:

|                                       |        |
|---------------------------------------|--------|
| Tensile strength, lb. per sq. in..... | 73,000 |
| Elastic limit, lb. per sq. in.....    | 38,000 |
| Drop test, foot-pounds.....           | 616    |

The variations in the tensile tests of the two series are no more than could be expected in steel of the same quality, but the drop test shows that there is 43 per cent. greater resistance to shocks in the specially treated steel over the regular product.

In both of the sets of tests given here, the conclusion to be drawn from the tensile tests alone is that there is very little difference in the quality of the steels tested, but the drop test leaves little doubt as to the superiority of certain steels over others.

HENRY M. HOWE, New York, N. Y. (communication to the Secretary \*):—Mr. Hall does well to bring up the impact test, for American engineers have given it neither the attention which it has received in Europe nor that to which it is entitled. I will reinforce what he says by showing further that, though in many cases it shows nothing more than the tensile does, yet in other and very important cases it measures the fineness of structure and the resultant valuable service qualities where the tensile test fails to.

If a specimen, *a*, Fig. 15, notched on its lower side midway of its

length and resting on massive supports at both ends, is broken by the impact of a falling ram, *c*, delivering a blow by means of a knife edge, *d*, the resistance which its bending and breaking offer to the progress of the ram reduces the energy of the blow. We know from the mass of the ram and the height from which it falls, its energy at the instant of impact, and we measure by appropriate means the energy left in the ram after it has broken the specimen. Subtracting the latter from the former we get the energy consumed in bending and breaking the specimen. This quantity is called variously the "resilience," a name the propriety of which is at least questionable,<sup>1</sup> the "energy absorbed," and "the resistance to impact."<sup>2</sup> This latter, which seems to me descriptive and indicative enough, I shall use, abbreviating it to "impact-resistance."

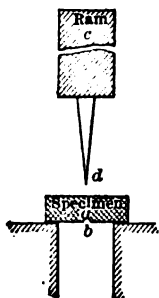


FIG. 15.—THE NOTCHED BAR IMPACT TEST, AFTER FRÉMONT.

*Fragility.*—Though "fragile" taken generically means "easily broken," whether by slow or sudden stress, in discussing the properties of the materials of construction it is habitually used in the sense of "easily broken by shock." As in general it is more convenient to speak of the strength rather than of the "weakness" of our materials, as we specify a certain minimum of strength, elasticity, and ductility rather than a certain maximum of weakness, inelasticity, and brittleness, specifying the positive rather than the negative, I

<sup>1</sup> Resilience.—"The quantity of work given back by a body that is compressed to a certain limit, then allowed freely to recover itself, as a spring under pressure suddenly relaxed." (Standard Dictionary of the English Language.) This would seem to cover only the work done in the elastic deformation of the specimen, and not to include that done in its plastic deformation prior to rupture, whereas what the impact test determines is the sum of these two quantities. In French one generally finds "Resilience" used; in German one often meets "Specifische Schlagarbeit," the impact resistance for conventional conditions. Its literal translation, "Specific blow work," though short and clear, would be jargon.

<sup>2</sup> Capt. H. Riall Sankey, Sixth Report Alloys Research Committee, *Proceedings of the Institution of Mechanical Engineers*, Feb., 1904, p. 160.

once again coin a word "infragility," the ability to resist shock, as convenient in discussing this subject.

Thus the property determined by the impact test is the "infragility," and the measure of that property is the "impact-resistance," as "specific gravity" is the measure of density, "dollars" of money, and "calories" of heat. Some good writers have indeed measured the infragility by the deformation up to the point of rupture; but, though this is related to the work done in rupture, yet the relation is far from fixed, and it is the latter that should be taken as the true measure of infragility.

*The Various Impact Test Machines.*—In the machine of Frémont, to whose initiative the existence of the notched-bar impact test is due, the energy which the ram retains after breaking the specimen is shown by the degree to which it compresses some springs which it strikes immediately thereafter. The Howe and Levy tests referred to in these remarks were made with the Frémont machine.

In Charpy's machine<sup>3</sup>, now in wider use, and in that of Sankey, the specimen lies at the bottom of the course of a pendulum, and the energy which the pendulum retains after breaking the specimen is shown by the height to which it swings up, as it then keeps on its way.

In the Guillery machine the energy absorbed in breaking the specimen is measured by the lessening of the velocity of a fly-wheel carrying the knife edge which delivers the impact.

In the methods of Seaton and Jude, Brinell, and Kirkaldy the impact-resistance is measured by the number of blows needed to break the test piece. The arrangement of the test piece in the Seaton and Jude method is like that of Frémont. But Brinell and Kirkaldy notch their bars in the middle of two opposite sides, support them at one end only, and break them by a blow delivered on the overhanging end, sometimes with the notches in the upper and lower sides of the test pieces, and sometimes on the vertical sides. Izod's method is like Charpy's except that his test piece is supported at one end only, and is struck on the overhanging end.<sup>4</sup>

*Dimensions of Test Pieces.*—In spite of the great advantages which would result from having all test pieces for the impact test of one set of standard dimensions, practical considerations have thus far prevented this. Hence, with the hope of making results comparable,

<sup>3</sup> *Engineering*, vol. lxxxix, p. 78 (Jan. 21, 1910).

<sup>4</sup> For a description of these methods and of extensive tests of their concordance see Harbord, *Proceedings of the Institution of Mechanical Engineers*, Nov. 20, 1908, p. 921, and *Engineering*, vol. lxxxvi, p. 736 (Nov. 27, 1908).

two standard sizes have been proposed, geometrically similar, one 30 by 30 by 180 mm., with a distance of 120 mm. between supports, with a nick 15 mm. deep, rounded at its bottom to a radius of 2 mm., and the other with one-third of these dimensions (Mesnager)<sup>6</sup>.

Unfortunately the expectation that these two sets of dimensions would give comparable results has not thus far been fulfilled. The results of Bartel, Ehrensberger, and Charpy show concordantly that the smaller test piece gives less impact-resistance. The difference increases with the impact-resistance, being smaller in the case of fragile and larger in the case of infragile metals. Indeed, on reflection we see that this expectation was not well founded. That part of the resistance which counts most is that of the fiber at the top of the notch. Once this fiber has parted, rupture will tear back through the remainder of the section. On one hand it is not at all clear that the concentration of stress on this fiber is proportional to the depth of the test piece; and on the other hand for given concentration of stress there, it is far from clear that doubling the depth of the test piece will double the resistance to tearing back, once a crack has started. What happens under these dynamic conditions is not to be traced out beforehand with confidence.

But these dimensions are often departed from. Test pieces 30 by 10 by 8 mm. with a 1-mm. notch are often used, *e. g.*, in the tests of Wolff<sup>7</sup> and of Howe and Levy, and Frémont himself advises that they should be 35 by 10 by 8 mm.<sup>7</sup>

*How Harmonious are the Results of the Impact Test?*—Though an exaggerated idea of the lack of harmony among the results of the impact test is about, we must admit that their real harmony, under some conditions as yet unexplained, is less than might be expected.

<sup>6</sup> Charpy, Report of Committee 25 on Impact Tests, *Proceedings of the International Association for Testing Materials*, II, 6 Congress, IV, 1, p. 2, 1913.

"The French navy uses a test piece 30 mm. square and 160 mm. long resting on knife edges 120 mm. apart. The notch consists of a hole 8 mm. in diameter, tangential to the axis of the bar and joined to the surface by a saw-cut; thus the intact section of the bar is to be half the total section. The hole to be pierced with a drill and to be finished with the aid of a reamer.

"The tup, of the weight of 18 kg., shall fall in the direction of the axis of the saw-cut; the hammer shall form an angle of 50° rounded off to a radius of 2 mm; the height of fall is always to be 1 m.

"To pass, the bars must stand at least five blows without breaking; after the fifth blow they should be bent under an angle of at least 147°, corresponding to a mean deformation of 180—147  
— 5 = 6° 30' maximum per blow." (Charpy, *id.*, V Congress, 1909, III, 1.)

<sup>7</sup> E. B. Wolff, *Proceedings of the International Association for Testing Materials*, II, VI Congress, 1912.

<sup>7</sup> Frémont, *id.*, II, IV, 2, p. 4.

Indeed the harmony is so poor in some cases that only after averaging a large number of results can any accurate inferences be drawn. The discord is not to be explained away by the incompetence of the operator, because it occurs even under most competent observation. I learn privately of marked discord in the results reached by a very competent French experimenter, under conditions which would naturally be expected to yield harmonious results. Harbord's results, too, are less concordant than we should expect in view of his well-known accuracy, as is shown by my analysis of his data in columns 2, 4, and 6 of Table I. The "Mean deviation in percentage of the mean resistance" given in these columns is found by calculating (1) the mean resistance of each steel in a given physical condition, (2) the deviation of each result from this mean in percentage of this mean, and hence (3) the mean of these percentages. These mean deviations run from 1 to 24 per cent., and the mean of all these means in these three columns is nearly 9 per cent.

TABLE I.—*Harmony of Impact-Test Results, Analysis of Harbord's Data.*

| Carbon, per cent.                |                                                                                     | Deviation from the Mean in the Untreated Steel. |      |        |      |        |      | Total Amplitude of Deviation. |              |           |             |              |           |             |              |           |
|----------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------|------|--------|------|--------|------|-------------------------------|--------------|-----------|-------------|--------------|-----------|-------------|--------------|-----------|
|                                  |                                                                                     | 0.262.                                          |      | 0.325. |      | 0.409. |      | 0.262                         |              |           | 0.325       |              |           | 0.409.      |              |           |
|                                  |                                                                                     | Deviation Per Cent. of Mean Resistance.         |      |        |      |        |      | Un-treated.                   | Over-heated. | Restored. | Un-treated. | Over-heated. | Restored. | Un-treated. | Over-heated. | Restored. |
|                                  |                                                                                     | Mean                                            | Max. | Mean   | Max. | Mean   | Max. |                               |              |           |             |              |           |             |              |           |
| METHOD.                          |                                                                                     | Mean                                            | Max. | Mean   | Max. | Mean   | Max. | Un-treated.                   | Over-heated. | Restored. | Un-treated. | Over-heated. | Restored. | Un-treated. | Over-heated. | Restored. |
|                                  | 1.                                                                                  | 2.                                              | 3.   | 4.     | 5.   | 6.     | 7.   | 8.                            | 9.           | 10.       | 11.         | 12.          | 13.       | 14.         | 15.          | 16.       |
| Seaton and Jude...               |  | 4                                               | 14   | 10     | 19   | 21     | 32   | 16                            | 68           | 60        | 35          | 55           | 48        | 48          | 50           | 92        |
| Frémont b .....                  |  | 7                                               | 13   | 8      | 11   | 7      | 39   | 25                            | 30           | 22        | 20          | 14           | 78        | 39          | 16           | 109       |
| Izod.....                        |  | 2                                               | 4    | 19     | 31   | 4      | 40   | 7                             | 35           | 22        | 49          | 9            | 19        | 64          | 31           | 33        |
| Kirkaldy (notch horizontal)..... |  | 15a                                             | 15a  | 6a     | 6a   | 4a     | 4a   | 30                            | 28           | 24        | 12          | 58           | 29        | 8           | 60           | 29        |
| Kirkaldy (notch vertical).....   |  | 1                                               | 1    | 4      | 8    | 1      | 2    | 1                             | 27           | 37        | 13          | 20           | 37        | 4           | 47           | 50        |
| Average .....                    |                                                                                     | 4.8                                             |      | 9.4    |      | 11.4   |      |                               |              |           |             |              |           |             |              |           |

NOTE:—This table is based on Harbord's data, Table IX, *Engineering*, vol. lxxxvi, p. 769 (Dec. 4, 1908). I have corrected certain apparent misprints in the original.

a Two tests only.

b The notch in the Frémont test is often if not usually rounded as here shown. In Mr. Harbord's test the notch was a sharp inverted "V."

TABLE II.—*Harmony of Impact-Test Results in Certain Tests of Howe and Levy, Compared with Tensile Tests by Norsworthy on the Same Specimens.*

| Steel No. IV. Carbon, 0.21; Silicon, 0.039; Manganese, 0.05; Phosphorus, 0.013; Sulphur, 0.010 per cent. |       |                    |                  |                       |                             |                  |                       |                             |                  |                       |                             |                  |                 |                             |                  |                 |
|----------------------------------------------------------------------------------------------------------|-------|--------------------|------------------|-----------------------|-----------------------------|------------------|-----------------------|-----------------------------|------------------|-----------------------|-----------------------------|------------------|-----------------|-----------------------------|------------------|-----------------|
| Heat Treatment, <sup>a</sup>                                                                             |       | Impact-Resistance. |                  |                       | Tensacity.                  |                  |                       | Yield Point.                |                  |                       | Elongation in 4 Inches.     |                  |                 | Contraction of Area.        |                  |                 |
| 1.                                                                                                       | 2.    | 3.                 | 4.               | 5.                    | 6.                          | 7.               | 8.                    | 9.                          | 10.              | 11.                   | 12.                         | 13.              | 14.             | 15.                         | 16.              | 17.             |
| Cooled from 900° to 680° in 710° for Hours.                                                              |       |                    | Individual Tests | Mean Kgm. per Sq. Mm. | Mean Devia- tion, Per Cent. | Individual Tests | Mean, Lb. per Sq. In. | Mean Devia- tion, Per Cent. | Individual Tests | Mean, Lb. per Sq. In. | Mean Devia- tion, Per Cent. | Individual Tests | Mean, Per Cent. | Mean Devia- tion, Per Cent. | Individual Tests | Mean, Per Cent. |
| Cooled from 900° to 680° in                                                                              |       |                    |                  |                       |                             |                  |                       |                             |                  |                       |                             |                  |                 |                             |                  |                 |
| Air                                                                                                      | Nil   | Air                | 0.360            |                       |                             | 56,370           |                       |                             | 40,610           |                       |                             | 21.25            |                 |                             | 66.08            |                 |
| Air                                                                                                      | Nil   | Air                |                  | 0.373                 | 4.8                         | 56,080           | 60,800                | 5.9                         | 41,600           | 44,300                | 7.2                         | 20.25            | 20.5            | 3.                          | 64.08            | 18.             |
| Air                                                                                                      | Nil   | Air                |                  |                       |                             | 64,240           |                       |                             | 47,986           |                       |                             | 19.5             |                 |                             | 60.54            | 3.0             |
| Air                                                                                                      | Nil   | Air                |                  |                       |                             | 64,535           |                       |                             | 47,036           |                       |                             | 21.0             |                 |                             | 61.95            |                 |
| Furnace                                                                                                  | Nil   | Air                | 0.029            | 0.025                 | 16.0                        | 57,870           | 57,150                | 2.0                         | 37,490           | 37,260                | 2.2                         | 17.75            | 18.02           | 1.9                         | 53.46            | 2.8             |
| Furnace                                                                                                  | Nil   | Air                | 0.021            |                       |                             | 56,500           |                       |                             | 37,900           |                       |                             | 18.50            |                 |                             | 53.00            |                 |
| Furnace                                                                                                  | Nil   | Air                |                  |                       |                             | 54,325           |                       |                             | 35,610           |                       |                             | 18.25            |                 |                             | 56.37            |                 |
| Furnace                                                                                                  | Nil   | Air                |                  |                       |                             | 57,412           |                       |                             | 38,150           |                       |                             | 17.60            |                 |                             | 55.52            |                 |
| Furnace                                                                                                  | Nil   | Furnace            |                  |                       |                             | 53,853           | 54,570                | 1.4                         | 36,008           | 34,980                | 3.1                         | 22.25            | 20.52           | 8.4                         | 57.66            | 0.7             |
| Furnace                                                                                                  | Nil   | Furnace            |                  | 0.070                 | 21.4                        | 55,317           |                       |                             | 33,858           |                       |                             | 18.80            |                 |                             | 58.46            |                 |
| Furnace                                                                                                  | 1.5   | Air                |                  |                       |                             | 55,270           | 55,500                | 0.4                         | 35,970           | 35,260                | 1.3                         | 19.25            | 20.58           | 4.6                         | 57.57            | 1.3             |
| Furnace                                                                                                  | 1.5   | Air                |                  |                       |                             | 56,360           |                       |                             | 34,640           |                       |                             | 20.50            |                 |                             | 56.96            |                 |
| Furnace                                                                                                  | 1.5   | Air                |                  | 0.018                 | Nil                         | 56,860           |                       |                             | 34,974           |                       |                             | 22.00            |                 |                             | 57.09            |                 |
| Furnace                                                                                                  | 23.75 | Air                |                  |                       |                             | 59,400           |                       |                             | 40,510           |                       |                             | 18.50            |                 |                             | 57.54            |                 |
| Furnace                                                                                                  | 23.75 | Air                |                  |                       |                             | 57,060           | 57,560                | 2.                          | 38,370           | 38,150                | 4.3                         | 21.00            | 20.23           | 6.7                         | 59.61            | 1.9             |
| Furnace                                                                                                  | 22.5  | Air                |                  |                       |                             | 56,285           |                       |                             | 35,660           |                       |                             | 21.20            |                 |                             | 60.61            |                 |
| Furnace                                                                                                  | 22.5  | Furnace            |                  |                       |                             | 56,055           |                       |                             | 37,108           |                       |                             | 22.2             |                 |                             | 60.45            |                 |
| Furnace                                                                                                  | 22.5  | Furnace            |                  | 0.032                 | 5.9                         | 56,310           | 56,180                | 0.6                         | 33,558           | 35,565                | 2.8                         | 21.0             | 21.55           | 2.6                         | 59.94            | 0.4             |
| Furnace                                                                                                  | 22.5  | Furnace            |                  | 0.036                 |                             | 56,620           |                       |                             | 35,750           |                       |                             | 22.0             |                 |                             | 60.19            |                 |
| Furnace                                                                                                  | 22.5  | Furnace            |                  |                       |                             | 55,550           |                       |                             | 35,946           |                       |                             | 21.0             |                 |                             | 60.58            |                 |
|                                                                                                          |       |                    | Mean.            |                       | 9.6                         |                  |                       | 2.0                         |                  |                       | 3.5                         |                  |                 | 4.4                         |                  | 1.7             |

<sup>a</sup> Below 300° all bars were cooled in air; after machining they were reheated to 800° and cooled in the furnace.

<sup>b</sup> The "mean deviation" refers to the mean deviation from the mean in percentage of that mean. This quantity tends to increase as the absolute quantity of any characteristic increases.

<sup>c</sup> Elongation measured on 6 inches instead of 4 inches.



The deviations in the impact-resistance results of Howe and Levy. Table II, column 6, are of this same order of magnitude, running from 0 to 21.4, or on an average 9.6 per cent. These deviations are much greater than those in the tensile tests made by Prof. L. D, Norsworthy with these same specimens, as shown in columns 9, 12, 15, and 18 for comparison. These run from 0.6 per cent. in the case of tenacity to 8.4 per cent. in the case of elongation, and with a general mean of 2.9 per cent., or less than one-third that of the mean deviations of the impact-resistance. The order of harmony is as follows:

| Property.                | Mean Deviation<br>from the Mean.<br>Per Cent. |
|--------------------------|-----------------------------------------------|
| Contraction of area..... | 1.7                                           |
| Tensile strength.....    | 2.0                                           |
| Yield point.....         | 3.5                                           |
| Elongation.....          | 4.4                                           |
| Impact-resistance.....   | 9.6                                           |

The manner in which Harbord presented his data, shown in columns 11 to 16 of Table I, seems to me to exaggerate the discord. The mean deviation from the mean seems to me a better index of harmony than the total amplitude of deviation, at least when the number of observations varies.<sup>8</sup> It is clear that the total amplitude is likely to increase with the number of observations, though the mean deviation is likely to decrease.

Again the Paris-Lyon-Mediterranean railroad reports that the impact-resistance may vary even as 4:1 in the most homogeneous steels.<sup>9</sup>

But these discords seem referable rather to some peculiarity of the specimens tested than to the method itself, for Goerens and Hartel's results are extremely harmonious, as is shown by my analysis of them

<sup>8</sup> It is quite true that the mean deviation in percentage of the mean is a false measure of accuracy when the quantities to be measured differ greatly. For instance, these percentages are incomparably greater if we are determining manganese in a wrought iron which contains only 0.02 per cent. of that metal than if we are determining it in an 80 per cent. ferro-manganese. But the quantities to be measured by the tensile and by the impact test are of the same order of magnitude. The fact that in the tenacity numbers are in tens of thousands while those of the impact-resistance are only in fractions has nothing whatsoever to do with it, as we see when we compare results reported in tons with the same ones when reported in pounds, or those reported in kilograms with the same results reported in milligrams. The scale which we choose for reporting our results has absolutely no influence on the deviation from the mean in percentage of that mean.

<sup>9</sup> *Proceedings of the International Association for Testing Materials*, II, VI Congress, 1912, IV, 5, p. 10.

"Even among those metals which are regarded as the most homogeneous (crucible steels, electro-steels), the resiliences vary from one value up to double that value in distances of a few cm. Within parts a metre or two apart the variations may even be four times as large and more."

in Table III. To explain, they tested 117 pairs of test-pieces, in the form of rolled bars 1.18 by 0.39 in. (30 by 10 mm.), some from the top and some from the bottom of two common commercial steel ingots. The results are given with three significant figures. In 19 pairs, or about 16 per cent. of the whole, the two specimens of each pair gave identical results. In the 98 other pairs the two results of each pair were closely alike. In one series of 25 pairs the greatest deviation in any one pair of tests from the mean of that pair was only 2.8 per cent. of that mean. The average of such deviations was only 0.6 per cent. in this series, and only 0.8 per cent. in another series of 30 pairs, a degree of harmony which compares favorably with that reached in the tensile test in the most careful hands.

TABLE III.—*Harmony of Impact-Test Results, in Data of Goerens and Hartel.*<sup>a</sup>

| Chemical Composition.. |       |      | Table No.<br>(G.+H.) | Steel No. | Part of Ingot. | Number of Pairs of Specimens. | Number of Pairs which Agreed Exactly. | Average Deviation from Mean. |                                      | Maximum Deviation from Mean. |                                      |
|------------------------|-------|------|----------------------|-----------|----------------|-------------------------------|---------------------------------------|------------------------------|--------------------------------------|------------------------------|--------------------------------------|
| C.                     | Si.   | Mn.  |                      |           |                |                               |                                       | Kgm. per Sq. Mm.             | In Per-centage of the Several Means. | Kgm. per Sq. Mm.             | In Per-centage of the Several Means. |
| 0.050                  | Nil   | 0.46 | 2                    | 1         | Top            | 31                            | 5                                     | 0.0034                       | 1.8                                  | 0.013                        | 7.4                                  |
| 0.089                  | Nil   | 0.38 | 3                    | 1         | Bottom         | 25                            | 4                                     | 0.0020                       | 0.6                                  | 0.006                        | 2.8                                  |
| 0.084                  | Trace | 0.38 | 4                    | 2         | Top            | 30                            | 8                                     | 0.0018                       | 0.8                                  | 0.006                        | 4.1                                  |
| 0.085                  | Trace | 0.38 | 5                    | 2         | Bottom         | 31                            | 2                                     | 0.0053                       | 2.1                                  | 0.021                        | 10.7                                 |

<sup>a</sup> Goerens and Hartel, *Zeit. Anorg. Chem.*, 1913, 81, p. 130.

*Cause of Discordance.*—Why should the impact results be so much more discordant in some cases than the tensile results? One reason which lies close at hand is the greater effect in the former of any heterogeneousness. The particles at the very crotch of the notch have a disproportionate influence on the resistance which the test piece as a whole offers to rupture. Should it happen that a small particle of slag abuts on this crotch, or that the crotch communicates with a weak cleavage plane, a crack will here start readily. Should the crotch of a duplicate test piece be better situated the resistance to rupture should be much greater. In the tensile test local defects and local misfortunes of environment should have no such serious results.

It is antecedently probable that the impact results should be more harmonious in very fine-grained steel than in that which is coarse-grained, because in the former there is less difference between specimens in regard to what is present at the top of the notch than in the latter. To take an extreme case, in a steel made up of grains all of which are alike, if those grains are infinitely small, then the condi-

tions of the notch-top will be the same wherever that notch happens to fall in the test piece; but if those grains are extremely large, the direction of the cleavage of the grains in which the notch ends might have very great effect. If those cleavages in several of the grains ran directly across the bar the impact-resistance would be much less than if they were inclined at  $45^\circ$ . In the data in Fig. 16 there is a straw

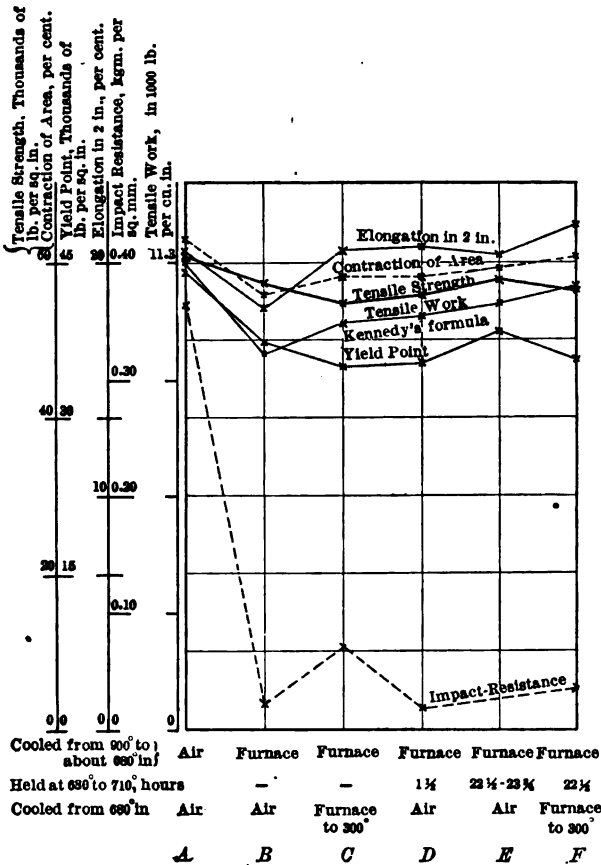


FIG. 16.—THE IMPACT TEST SHOWS THE INFLUENCE OF HEAT TREATMENT MORE CLEARLY THAN THE TENSILE TEST.

Data of Howe and Levy. Influence of Prolonging the Stay in the Divorcing Range on the Mechanical Properties of Steel No. IV, 0.21 per cent. of carbon, 0.05 of manganese, 0.013 of phosphorus, 0.039 of silicon, and 0.010 of sulphur.

which blows in this direction. The finest grained specimens are those of ordinate A, air cooled from  $900^\circ$ , and the impact tests of these are very harmonious, as shown in Table II.

Further effects flowing from the special mode of attack in the impact test are pointed out on p. (—)

The opponents of the impact test may point to the discordance of its results as a disadvantage, calling for many repetitions of the test itself. Its advocates may reply that this capacity for discordance is a great advantage, because it detects heterogeneousness, and they may propose that future specifications for important objects shall specify a maximum which the deviation shall not exceed, to the end of excluding heterogeneous material, questioning, in passing, whether the needed repetitions of the impact test need cost more than a single tensile test.

*Effect of Variations in the Speed of Impact on the Results of the Impact Test.*—In the tensile test, as the straining rate increases, the tensile strength increases moderately with it according to the great bulk of evidence, and the elongation also increases in many cases, though in others this increase is so slight as to escape observation. How is it with the impact test?

Duguet found that "the extreme deformations are, in the case of soft steel submitted to bending, very sensibly the same, whether they be produced slowly by hydraulic pressure or by the impact of a tup."<sup>10</sup>

Kick's<sup>11</sup> experiments indicated that "the velocity of fall has only an insignificant influence on the magnitude of the deformation in impact bending tests."<sup>12</sup>

Charpy reported that the impact-resistance was independent of the height of drop, and that the results of notched bar impact tests differed but little from those of tensile tests.

On the other hand, Frémont, admitting that the former law is true for many steels, finds that for others the resistance varies materially with the height, and therefore recommends either a minimum drop of 4 m., or an equivalent impact speed. Beyond this he advises that the anvil weigh at least 40 times as much as the tup.

Again, the Paris-Lyons-Mediterranean railroad<sup>13</sup> shows that the observed impact-resistance may be about twice as great with a fall of 4 m. (13 ft. 1 in.) as with one of about 1.25 m. (4 ft. 11 in.)

Finally Pérot and Levy<sup>14</sup> found the deformation in the transverse notched bar impact test was inversely as the speed of impact, becoming nil, so that the specimen broke without any permanent set, if impact and rupture were extremely rapid.

<sup>10</sup> *Proceedings of the International Association for Testing Materials*, I, 1909, III, 1, pp. 6 and 7.

<sup>11</sup> *Proceedings of the International Association for Testing Materials*, V Congress, 1909, III, 1, p. 8.

<sup>12</sup> *Id.*, VI Congress, 1912, IV, 2, p. 4.

<sup>13</sup> *Proceedings of the International Association for Testing Materials*, II, VI Congress, 1912, IV, 5, pp. 5, 11.

<sup>14</sup> *Comptes rendus*, vol. cxxxix, p. 1198 (1904).

Thus the present evidence as to the influence of the rate of straining is contradictory, suggesting that accelerating the straining has more than one immediate effect, and that the sign of these effects is not constant, so that the resultant effect may vary in sign or may be nil.

One's impression is that a rapid impact is especially trying to fragile—*e. g.*, phosphoric—steel. The discrepancies in the evidence may be due to differences in the fragility of the metals tested, the deformation of the fragile metals decreasing and that of the inflexible ones increasing with the speed of impact. To test this hypothesis is an easy and useful line of investigation.

*Has the Impact Test Reason to Exist?*—This question is divisible into two: (A) Does it teach anything that cannot be learnt more readily from other tests? (B) If it does, is its special teaching of value?

Breuil<sup>15</sup> is not alone in believing that the impact test teaches nothing that cannot be learnt as easily from a proper interpretation of the tensile test, and hence that in view of its reproducing the conditions of service much less closely than the tensile test, it should be abandoned.

Admitting freely that there are many materials which would be classified in much the same way by the impact and by the tensile test, I will now inquire whether there are not other materials which are classified differently by these two tests, or in short whether the impact test is not a specific test for certain properties.

The impact test measures the work done in rupture, whereas the tensile test as usually reported measures not the corresponding work, the tensile work, but stresses and strains which are the components of work, and plasticity. The elastic limit and the tensile strength are two stresses. The elongation measures the plastic strain. The contraction of area measures plasticity. Hence the impact-resistance, measuring work, must needs teach something which none of these quantities in and by itself can teach, or in short the impact test does teach something which the tensile test, as reported, does not teach.

The question then arises, (C) Does the impact test teach anything which the tensile test is incapable of teaching? There is another question equivalent to this: (D) Is the impact resistance proportional to the tensile work? If it is, then the tensile work, as found by measuring the tensile stress-strain diagram, teaches all that the impact test teaches. This last is the important question for our present attention.

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<sup>15</sup> *Journal of the Iron and Steel Institute*, Supplement to vol. lxx, p. 90 (1904.)

*Kennedy's Formula.*—Unfortunately the tensile work is rarely recorded and more rarely reported. Autographic stress-strain diagrams are rarely taken, and still more rarely accessible. To plot the diagram from direct observations would be most laborious, indeed quite impossible under existing industrial testing conditions.

To meet this need Kennedy<sup>16</sup> proposes a formula which gives a rough approximation to the tensile work, which is the product of the total strain, elastic plus plastic, into the average stress. It is

$$\frac{\text{Yield point} + 2 \text{ Tensile strength}}{3} \times \frac{\text{Elongation}}{\text{Measured length}} = \text{Energy per cubic inch.}$$

Here "elongation" means the final elongation as usually measured, which is the plastic elongation. This formula leaves out of consideration the elastic elongation. Its assigning to the maximum stress or tensile strength double the value assigned to the stress at the yield point is of course only a very rough approximation, but quite close enough for the sharp contrasts which I will now point out.

In order to learn whether the impact test teaches anything which the tensile test teaches or can thus be made to teach, by asking whether the impact-resistance is proportional to any of the four tensile properties or to the tensile work, I plot in Figs. 16, 17, and 18 these six properties in a way which must needs show at once whether they vary proportionally or not.

This I do by selecting for each property such a scale for ordinates as will bring the beginning of the six curves to approximately the same height, and by making the origin equal to zero for all. If under these conditions the impact-resistance varied proportionally to any tensile property, work included, the impact-resistance curve would necessarily be closely parallel to the curve of that property. In fact there is not the first shadow of parallelism. The impact-resistance discloses losses of infragility which are hardly hinted at by the tensile properties. This is especially striking in Figs. 16 and 17.

Each of the series of tests which I thus analyze is made on a given steel after varying heat treatments. Figs. 17 and 18 represent tests by Roberts-Austen and Sankey on two of the former's steels, and Fig. 16 represents tensile and Frémont impact tests by Norsworthy, and Howe and Levy. Sankey showed in 1904 that his impact tests disclosed fragility which was undetected by the tensile test, in these and other cases.<sup>17</sup>

<sup>16</sup> Sir Alexander Kennedy's formula (Blount, Kirkaldy, and Sankey, *Engineering*, vol. lxxxix, p. 730 [June 3, 1910]).

<sup>17</sup> Sixth Report Alloys Research Committee, 1904, *Proceedings of the Institution of Mechanical Engineers*, Feb., 1904, p. 167.

Again the variations in impact-resistance in Figs. 19 and 20 differ greatly from those in any of the tensile properties and in the tensile work. So in Fig. 21 the loss of impact-resistance with increasing carbon content bears little resemblance to the decrease of tensile work.

Finally Wolff<sup>18</sup> raised the impact-resistance of a steel of 0.035 per cent. of carbon from an extremely small quantity, the impact-resistance of some pieces being only between 0.2 and 6 kgm., to between 20 and 25 kg.; yet the tensile properties were affected but little, the tensile strength rising about 12 per cent. from 33.8 kg. per square millimeter, with a maximum of 34.5, to 38 kg., and the elongation and contraction of area remaining practically unchanged. This was done simply by hastening the cooling so that it took 4 hr. from 1,100° to 20°, and thereby preventing not only pearlite divorce, which was complete in the slowly cooled specimens, but even the formation of pearlite. The description is not very full, but our inference is that this slightly hastened cooling left the eutectoid in the form of sorbite.

*Detailed Examination of Some of these Cases.*—The damage done to the 0.13 carbon steel, Fig. 17, by the divorcing annealing during the 12-hr. holding at 620°, ordinate *E*, is not clearly shown by the tensile tests, for many would hold that the gain in elongation and contraction of area nearly offsets the loss in elastic limit and the very moderate loss in tenacity. But this treatment destroys the impact-resistance almost completely.

Again, compare ordinates *D*, *E*, and *F* of Fig. 18. The inferiority of the specimens held  $\frac{1}{2}$  hr. at 1,100° and 12 hr. at 720°, and the superiority of that held 12 hr. at 620°, are hardly hinted at by the tensile-strength curve; and though they are indeed disclosed by the curves of elastic limit, elongation, and contraction of area, yet they are much more prominent in the impact-resistance curve.

In passing we may refer the inferiority caused by the 1,100°  $\frac{1}{2}$ -hr. holding to coarsening, and that caused by the 720° 12-hr. holding to pearlite divorce; and the superiority caused by the 620° 12-hr. holding to its being a quasi-sorbitizing drawing of the effects of the presumable cool rolling of the steel as received from the maker, a cool rolling indicated by the very small initial elongation and contraction of area, 6.25 and 18.76 per cent. respectively. It is good practice to improve such steel by rolling it cool or even cold, and then drawing it in this range of temperature. For the high elastic limit and impact-resistance thus obtained, the accompanying softness and cheapness of machining

<sup>18</sup> *Proceedings of the International Association for Testing Materials*, II, VI Congress, 1912. The steels contained C, 0.035; Si, 0.008; Mn, 0.32; P, 0.035; S, 0.056; Cu, 0.018; As, 0.027; N, 0.007.

are much greater than they can be made by hardening and tempering. So with Fig. 16. The passage through the transformation range was a sorbitizing air cooling for ordinate *A*, but for the other ordinates it was a furnace cooling, resulting in pearlitizing, and even in more or less advanced divorcing annealing, which was augmented by further exposure to divorcing annealing temperatures in the treatment of or-

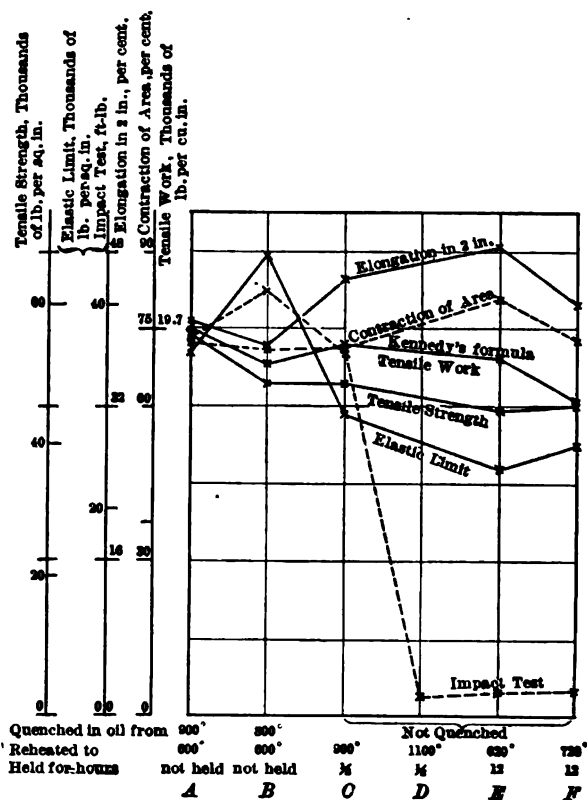


FIG. 17.—THE IMPACT TEST SHOWS THE INFLUENCE OF HEAT TREATMENT MORE CLEARLY THAN THE TENSILE TEST.

Properties of Steel of 0.13 per cent. of Carbon, Roberts-Austen and Sankey. Sixth Report Alloys Research Committee, Institution of Mechanical Engineers, London, 1904.

The steel contained: carbon 0.130, silicon 0.020, manganese 0.135, phosphorus 0.011, sulphur 0.020, arsenic 0.024.

ordinates *C* to *F* inclusive. The influence of this slow transformation and of the resultant de-sorbitizing and divorce is shown incomparably more clearly by the impact-resistance than by any or all of the tensile properties.



In Figs. 19 and 20 the strong maximum of impact-resistance when the tempering temperature reaches the 600°–700° range represents the sorbitic state, and the sharp decrease at 740°, on rising past  $A_{c1}$ ,

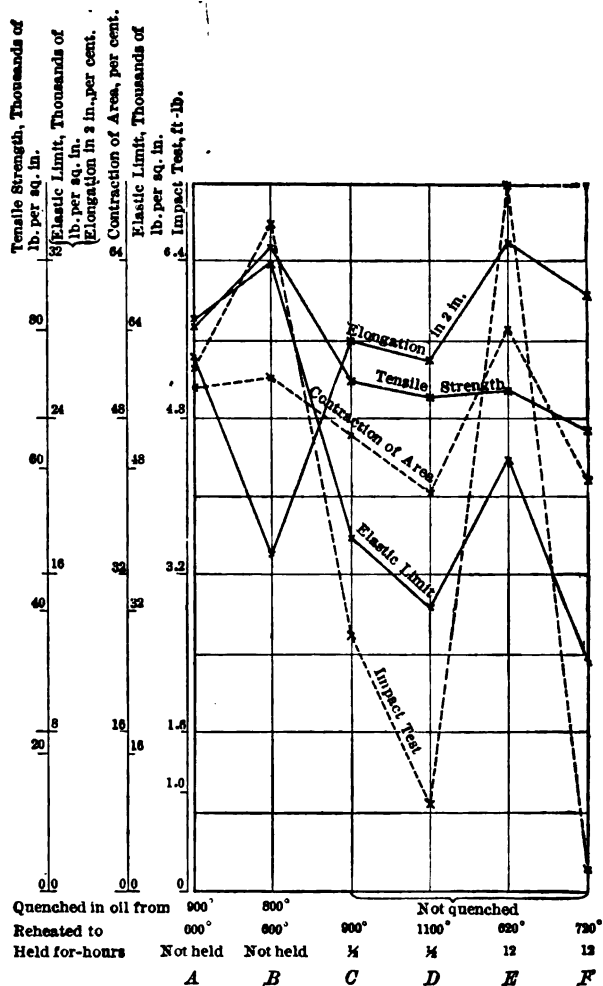


FIG. 18.—THE IMPACT TEST SHOWS THE INFLUENCE OF HEAT TREATMENT MORE CLEARLY THAN THE TENSILE TEST.

Properties of Steel of 0.468 Carbon, Roberts-Austen and Sankey. Sixth Report Alloys Research Committee, Institution of Mechanical Engineers, London, 1904.

The steel contained: carbon 0.468, silicon 0.072, manganese 0.160, phosphorus 0.016, sulphur 0.025, arsenic 0.007.

represents the substitution of pearlite for sorbite. These changes are indeed reflected in the tensile properties but less strikingly.

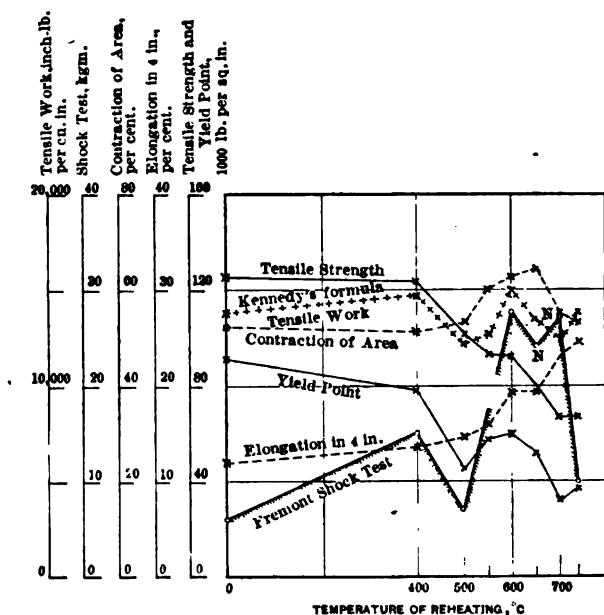


FIG. 19.—VARIATIONS IN THE TENSILE PROPERTIES AND THE IMPACT-RESISTANCE IN THE TEMPERING OF STEEL OF 0.40 CARBON, HOWE AND LEVY.

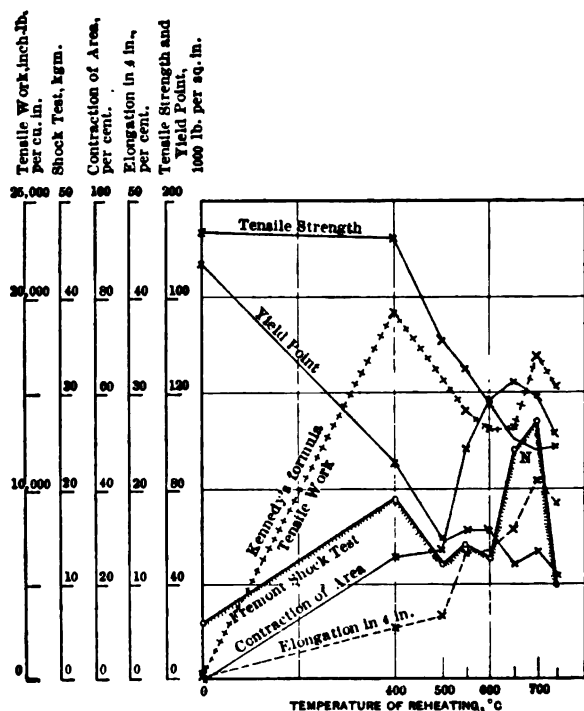


FIG. 20.—VARIATIONS IN THE TENSILE PROPERTIES AND IMPACT-RESISTANCE IN THE TEMPERING OF STEEL OF 0.46 CARBON AND 1.21 PER CENT. OF MANGANESE, HOWE AND LEVY.

Charpy<sup>19</sup> reports the properties of four metals which behaved substantially alike in the tensile test, and differed but little in the impact tensile test on notched cylindrical specimens, yet differed very strikingly in the transverse notched impact test, as is shown in Table IV. These results are not accidental, for they can "be produced at will by submitting the metals to suitable thermal treatment." It is of especial interest that metal B, which has such low impact-resistance, had its ferrite in large grains, and that when these are made small by heat treatment the impact-resistance rises to between 30 and 35 kgm., though the tensile results are but slightly affected.

TABLE IV.—*Charpy's Results Showing that the Impact Test Discloses Differences of Quality not Shown by the Tensile Test.*

| Metal. | Tensile Tests on Cylindrical Rods. |                 |             |                      |                             |                       | Notched Bar Impact Tests.   |                                  |
|--------|------------------------------------|-----------------|-------------|----------------------|-----------------------------|-----------------------|-----------------------------|----------------------------------|
|        | Tensile Strength.                  | Elastic Limit.  | Elongation. | Contraction of Area. | Total Work Done in Rupture. | Work Done in Necking. | Cylindrical.                | Prismatic.                       |
|        |                                    |                 |             |                      |                             |                       | Tension.                    | Bending.                         |
|        | Lb. per Sq. In.                    | Lb. per Sq. In. | Per Cent.   | Per Cent.            | Kgm.                        | Kgm.                  | Total Work Done in Rupture. | Work Done in Rupture per Sq. Cm. |
| A      | 59,900                             | 42,800          | 32.0        | 67.2                 | 179.5                       | 62                    | 84.49                       | 44                               |
| B      | 62,700                             | 42,700          | 32.0        | 65.6                 | 185                         | 40                    | 77.57                       | 2.7                              |
| C      | 64,140                             | 45,600          | 31.0        | 67.0                 | 192.2                       | 37                    | 74.04                       | 20.2                             |
| D      | 76,000                             | 49,900          | 25.0        | 51.8                 | 180.5                       | 35                    | 63.18                       | 18.7                             |

"Work done in necking" refers to the work done after passing the maximum stress, i. e., the stress representing the tensile strength, as deduced from a planimetric study of the stress-strain diagram.

Again in Mr. Hall's results with very low-carbon steel castings, the impact test discloses the great inferiority of the unannealed casting, and the decided superiority of the casting quenched from 900° and annealed at 680° over that air cooled from 900° and annealed at 710°, whereas the tensile test does not disclose that inferiority fully, and it almost completely conceals that superiority.

The reason why No. 14 is so much better than No. 13 is probably that it is sorbitic while No. 13 is pearlitic.

*The Impact-Resistance a Specific Test for Fineness of Structure.*—In every one of these cases which have just been cited, except Fig. 21, it is fineness of structure to which the impact test is so sensitive. It makes prominent the superiority of sorbitic over pearlitic steel, and of undivorced over divorced pearlite. And, though this evidence is

<sup>19</sup> *Proceedings of the International Association for Testing Materials*, I, V Congress, III, 1, pp. 15-16.

hardly extensive enough to justify a firm conclusion, yet it is in just this specific direction that the impact test would naturally be expected to excel. Though the stresses of the tensile test are presumably greater on the skin than at the axis of the test piece, yet the difference is far slighter than in the impact test, in which the extreme concentration of stress on the top of the notch gives rise to a tendency to cleave back into the material above the notch. Replace the impact test piece in your mind's eye with a like piece of slate with its cleavages transverse, and you will see that these cleavages would be much more damaging under transverse than under longitudinal stress. The long cleavage planes which coarse grains possess, and the longer con-

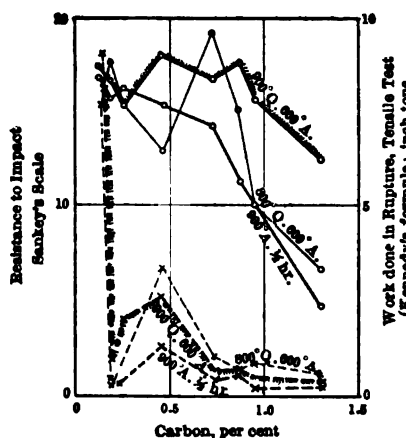


FIG. 21.—COMPARISON OF INFLUENCE OF CARBON ON THE IMPACT-RESISTANCE, AND ON THE WORK DONE IN TENSILE RUPTURE.

The broken lines refer to the work done in the Impact test, the solid lines to the work done in the Tensile test. From tables 5, 19, 20, 5a, 19a, and 20a of Roberts-Austen and Sankey. Sixth Report Alloys Research Committee, 1904.

tacts between pearlitic components than between sorbitic ones, should facilitate this cleaving action, this tendency to broom under the bending.

*Importance of Plasticity in the Impact Test.*—The work done in rupture consists of two parts, that done against the elastic resistance and that done against the plastic resistance. The tensile test discriminates between the elastic and the plastic deformation, but the impact test, if confined as it usually is to the work done, does not. Of these the work done in elastic deformation is by far the more important for hypo-elastic uses. The impact test might, at least in many cases, be made to discriminate between these two fractions of the work, and

thus its value for hypo-elastic uses might be increased greatly. A modification of it which should make this discrimination more general might be of great importance. The angle bent, as found by fitting the broken fragments together, might serve as a basis for calculating the plastic work roughly, and the remainder would represent the elastic work. I throw this out as worthy of thought.

It is on this account that the impact-resistance decreases so very abruptly as the carbon content increases. With this increment of carbon content the elastic limit indeed rises, and with it the elastic work increases; but this increment is completely overshadowed by the simultaneous decrease in plastic deformation. Thus the increase of the elastic limit with increasing carbon content, *e. g.*, in hot-rolled steel, is relatively slight, whereas the decrease in the plastic deformation, as indicated by the elongation, is very great.

This same consideration certainly influences the variations of the impact-resistance for given steel with varying heat treatment. But as we have seen the variations in the impact-resistance with the heat treatment are too great to be explained thus, and they must be referred in large part to variations in the fineness of structure.

*Are the Special Teachings of the Impact Test Valuable?*—The evidence which I have presented goes far to show that they are. There is the strongest reason to hold that the properties of the sorbitic state, which according to this evidence are detected so much more clearly by the impact than by the tensile test, are of the greatest value. Yet it is very important that the volume of this evidence should be increased greatly, for it is indeed rather scanty, though strikingly harmonious.

The evidence collected by Charpy<sup>20</sup> may here be considered, because it tends to show that the teachings of the impact test are valuable. The value of this evidence is indeed only indirectly contributory, because it does not show that the impact test teaches anything which the tensile test would not teach. Pierrard, the chief engineer of the Belgian naval construction, finds that the endurance of marine engine shafts increases with the impact-resistance of the material. The French navy adopted the impact test for machinery, especially for marine shafting, in 1893, and has extended its use, a fact which certainly suggests that this use has been found instructive. D'Ableiges, for many years President of the French armor plate commission, reported that this navy had found the impact test a very good guide to the ballistic resistance of armor plate. At Montlucon the use of a heat treatment shaped so as to give great impact-resistance lengthened the life of the rods of one steam hammer from an average of less than three months

<sup>20</sup> *Proceedings of the International Association for Testing Materials*, I, 1909, III, 1, p. 16.

to over six years, and of another from six months to three years. The experience with the heat-treated rods lasted some six years.

On the other hand it is reported that the Dutch navy found that steel cast armor plate, which showed but moderate resistance in the impact test, yet was "not fragile" in the ballistic tests. Without further information this result cannot be interpreted with confidence.

Promising as the impact test is for comparing different conditions of the same steel brought about by varying heat treatment, it may be very misleading if used for comparing steels of different carbon contents. For instance, low-carbon steel because of its plasticity excels that of higher carbon in impact-resistance not only very greatly, but to a degree which is wholly misleading as regards the most important class of uses, the hypo-elastic ones. In other words, in comparing steels differing materially in carbon content, the greater plasticity of the lower-carbon ones, though of secondary importance for most uses, yet gives them superiority as regards impact-resistance which has no corresponding service superiority. This is shown in Fig. 21.

For like reasons in comparing steels of different carbon contents the impact test is wholly misleading as to the endurance of repeated relatively light stresses or blows, of which a very great number is needed to cause rupture. The impact test reflects chiefly the work of the plastic deformation, whereas the resistance to indefinitely repeated stresses, whether suddenly or gently applied, depends not on the plasticity but on the elasticity of the material. For uses in which a very small number of severe blows is to be endured a low-carbon material should be used, but for those which imply a very great number of repetitions<sup>21</sup> of light blows a high-carbon material with high elastic limit is better fitted.

#### SUMMARY.

1. *Harmoniousness.*—The results of the impact test are usually much less harmonious than those of the tensile test. The deviations in one series are about five times as great as those in the tensile strength, and about double those in the elongation. Yet in one extended investigation the mean deviations are less than 1 per cent., i. e., not greater than in tensile testing. The discordance may be due to heterogeneousness of any kind, and especially to coarseness of structure.

2. *Speed of Impact.*—Though in many cases the impact-resistance is affected but little by the speed of impact, yet in others it increases

<sup>21</sup> See Stanton, *Proceedings of the International Association for Testing Materials*, VI Congress, 1912, V, 1, p. 6.

materially with that speed, reminding us that the tensile strength also increases slightly with the rate of straining, on the average of a large series of tests.

3. *Special Teaching.*—The impact test excels the tensile test very greatly in distinguishing between fine and coarse material, a distinction often of very great importance. It also excels the tensile test as a means of measuring the local injury done by flaws, sonims, segregation, etc.

4. *Limitation.*—Because it is affected very greatly by the plastic deformation, it is misleading as a basis for comparing steels of different carbon contents intended for hypo-elastic uses. Its use is rather for comparing varying states of a given steel due to varying heat treatments.

5. *Modification.*—It may be possible to increase its usefulness greatly by comparing the angle bent with the work done, and thus arriving at the hypo-elastic work, instead of as at present reporting the hypo- and hyper-elastic work together.

JOHN H. HALL, New York, N. Y. (communication to the Secretary \*):—The discussion of the paper, especially by Professor Howe, is so full that it leaves very little to say. As one of our members once said, when Professor Howe contributes a paper or discussion, it is so complete, and covers so thoroughly all possible aspects of the subject, that further discussion is far from easy.

Several points brought out are of great interest in their bearing upon the question of the applicability of the impact test to steel castings. In Professor Howe's discussion, he states that it has been found that the smaller tests give less impact resistance than the larger ones. The great difference in the impact resistance of tests cut from different parts of the same coupon of cast steel which has been subjected to heat treatment, has led me to think that a much larger test than any that has been yet used might be of value in examining such material. In particular, I have found that two steels which gave approximately equally good results in the Frémont test, were shown to be considerably different in their resistance to repeated heavy shocks when tested in a bar some 2.5 in. square. This was a very rough test, more or less in line with that used by Mr. Chancellor in making the experiments summarized in his most interesting discussion.

Professor Howe's point that steels of different carbon content should not be compared by the impact test, on account of the deficiency of plastic deformation in high-carbon steel, is well taken. As he says,

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\* Received Nov. 7, 1913.

for most uses the greater plasticity of the low-carbon steels is of secondary importance; and the property most desirable is the ability to resist relatively light stresses constantly repeated. Thus, for instance, we know that in locomotive axles a medium high-carbon steel will give a longer life than a low-carbon steel; and from this we might infer that it is best to use a high-carbon casting in machinery parts which in ordinary service will not be called upon to endure heavy stresses. In some special cases, however, this conclusion is not necessarily correct. For instance, some manufacturers of taxicabs use cast-steel front axles, and make a part of the casting so light that it will bend or break, and thus save the rest of the car, when the vehicle comes into collision with some heavy object. In service, many of these axles have been seriously bent in collisions, straightened and replaced in service, several times. Under ordinary conditions of service, a high-carbon steel in one of these axles will give longer life than a low-carbon steel, because, as ordinarily heat treated, the high-carbon steel possesses much greater strength and elastic limit, and hence a greater resistance to repeated light stresses. By proper heat treatment, however, a soft steel can be made to possess as much strength and endurance under repeated stress as a harder steel treated in the usual manner; and at the same time, the soft steel will possess a resistance to shock much greater than the hard steel will exhibit in any condition. The great plastic deformation of the soft steel in this case will not be of value under ordinary conditions of service; but will be of great value in case of a collision, in two ways: first, because the soft steel axle will be very much less apt to break and upset the car, to the discomfort of the occupants; and second, because such an axle can be bent and straightened more times than one made of more brittle steel. This, of course, is a very special case, but it is probable that many similar instances might be found.

With regard to Mr. Johnson's question as to whether a parallelism has been found to exist between the impact test and the shock test, I am not aware of any figures that have been published on this subject. Professor Howe's citations of the greatly increased life of marine engine shafts and of steam-hammer piston rods, so treated as to give great impact resistance, at least points to the probability that impact resistance and endurance to repeated stresses go together in some cases. The accompanying table of tests of cast steels, made in the White-Souther endurance testing machine, is based upon entirely too few bars to be much of an answer to Mr. Johnson's query. However, as far as they go, these figures are of value in illustrating what has just been said about the possibility of obtaining simultaneously



great impact resistance and great endurance to repeated stresses, in a soft cast steel. It will be seen by these figures that the softer steel has by suitable heat treatment been given a strength and elastic limit about equal to that of the harder steel, and that it possesses at the same time great impact resistance. In the endurance test, as the table shows, four bars of this steel so treated endured an average of 10,373,050 revolutions at a fiber stress of 28,270 lb. to the square inch, and an average of 823,950 revolutions additional at a fiber stress of 38,870 lb. to the square inch. Compared with this, we have on ten tests of harder steel, all treated alike (leaving out test C), an average of 3,805,000 revolutions at 28,270 lb. to the square inch for five bars; and an average of 10,451,240 revolutions at 28,270 lb. per square inch, and of 590,560 revolutions additional at 38,870 lb. per square inch, for five bars. It will also be seen that with one exception the softer steel in every case endured more revolutions than any test of the harder steel. No doubt, by heat treating the harder steel in the same way as the softer, both the tensile properties and the endurance figures for this steel can be improved; and therefore, if we are considering only the resistance to repeated light stresses, we should use the harder steel treated in the best way. But if we desire good resistance to repeated light stresses coupled with great impact resistance, we would use the softer steel heat treated, and kill two birds with one stone.

Mr. Stoughton and Dr. Campbell state that certain cast steels, which they tested, exhibited comparatively good tensile figures but gave very poor impact resistance; and that the fracture of this steel was coarse, as though the steel were badly overheated. My experience has been that in hypo-eutectoid cast steel cooled slowly from the annealing temperature (and by this I mean cooled at what is a slow rate in a large annealing furnace, a matter of a good many hours), the impact resistance is not particularly high, even in soft steel, and the microstructure consists of comparatively large grains of ferrite and pearlite. These steels so annealed habitually give quite good tensile properties, but rather poor impact resistance; and the impact tests break with the fracture described. This condition of course is often greatly exaggerated by extreme coarseness of microstructure, by under-annealing, or by great segregation of impurities. But the general type of fracture is typical, and very different from that of steel heat treated in such a way as to give higher impact figures, which, as Professor Howe has pointed out, are always an indication of truly fine microstructure. Of course, the lower the carbon and the

greater the plastic deformation of the steel in the impact test, the more striking the difference in the fracture of the steel.

As Professor Campbell says, the Frémont machine requires frequent calibration; indeed its mechanical construction is not very good, so that it frequently gets out of order, and when a great many tests are being made every day, a good deal of time is wasted in tinkering with the machine. Not having had experience with other designs of impact testing machines, I am unable to say whether they are open to the same criticism; from my general knowledge of their design, I imagine that they do not give as much trouble in handling as the Frémont machine, at least in its present form.

In conclusion, I wish to express my sincere thanks to the gentlemen who have so ably contributed to the discussion.

| No. | Cut from                 | C.        | Si.       | Mn.       | S.        | P.        | Treatment.    |         |
|-----|--------------------------|-----------|-----------|-----------|-----------|-----------|---------------|---------|
|     |                          |           |           |           |           |           | Heated to     | Cooled. |
|     |                          | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |               |         |
| A   | 4 in. sq.                | 0.42      | 0.46      | 0.73      | .....     | .....     | 900° 5.5 hr.  | Air     |
| B   | 4 in. sq.                | 0.44      | 0.38      | 0.59      | .....     | .....     | 700° 5.5 hr.  | Slowly  |
| C   | 4 in. sq.                | 0.46      | 0.42      | 0.71      | .....     | .....     | 690° 3 hr.    | Air     |
| D   | 4 in. sq.                | 0.36      | 0.54      | 0.71      | 0.049     | 0.051     | 690° 7 hr.    | Slowly  |
| E   | 4 in. sq.                | 0.47      | 0.56      | 0.73      | .....     | .....     | 920° 5 hr.    | Air     |
| F   | 4 in. sq.                | 0.43      | 0.46      | 0.65      | .....     | .....     | 690° 3 hr.    | Slowly  |
| G   | 1.25 by 2.5<br>by 12 in. | 0.23      | 0.31      | 1.07      | 0.037     | 0.047     | 900° 5.5 hr.  | Air     |
| H   | 4 in. sq.                | 0.27      | 0.46      | 0.71      | .....     | .....     | 700° 11 hr.   | Slowly  |
|     |                          |           |           |           |           |           | 900° 4 hr.    | Air     |
|     |                          |           |           |           |           |           | 700° 5 hr.    | Slowly  |
|     |                          |           |           |           |           |           | 900° 6 hr.    | Water   |
|     |                          |           |           |           |           |           | 680° 8 hr.    | Air     |
|     |                          |           |           |           |           |           | 900° 5 hr.    | Water   |
|     |                          |           |           |           |           |           | 680° 8.75 hr. | Air     |

| No. | Tensile Strength.<br>Lb. per Sq. In. | Elastic Limit.<br>Lb. per Sq. In. | Extension in 2 In.<br>Per Cent. | Contraction.<br>Per Cent. | Frémont |
|-----|--------------------------------------|-----------------------------------|---------------------------------|---------------------------|---------|
|     |                                      |                                   |                                 |                           |         |
| A   | 82,100                               | 45,990                            | 8.41                            | 9.79                      | 7.5     |
| B   | 76,170                               | 42,990                            | 14.64                           | 15.11                     | 5.0     |
| C   | 76,730                               | 42,750                            | 12.05                           | 15.81                     | 5.0     |
| D   | 73,200                               | 40,630                            | 14.08                           | 19.79                     | 10.0    |
| E   | 79,590                               | 44,020                            | 10.94                           | 11.49                     | 8.5     |
| F   | 73,200                               | 40,200                            | 12.5                            | 16.4                      | 7.5     |
| G   | 67,200                               | 44,400                            | 14.19                           | 31.3                      | 32.0    |
| H   | 78,710                               | 46,400                            | 22.8                            | 24.21                     | 17.0    |

*Endurance Tests.*

| No. | Fiber Stress. | Deflection, | Revolutions No. 1 End. | Revolutions No. 2 End.  |
|-----|---------------|-------------|------------------------|-------------------------|
| A   | 28,270        | 0.06        | 10,709,600             | 10,709,600              |
| B   | 28,270        | 0.06        | 4,685,000 (B)          | 6,708,000 (B)           |
| C   | 28,270        | 0.06        | 2,796,800 (B)          | 10,000,000 <sup>a</sup> |
| D   | 28,270        | 0.06        | 3,474,300 (B)          | 2,368,700 (B)           |
| E   | 28,270        | 0.06        | 10,158,400             | 1,789,400 (B)           |
| F   | 28,270        | 0.06        | 10,339,300             | 10,339,300              |
| G   | 28,270        | 0.06        | 10,475,100             | 10,475,100              |
| H   | 28,270        | 0.06        | 10,271,000             | 10,271,000              |

| No. | Fiber Stress. | Revolutions No. 1 End. | Revolutions No. 2 End |
|-----|---------------|------------------------|-----------------------|
| A   | 38,870        | 280,800 (B)            | 302,000 (B)           |
| B   | .....         | .....                  | .....                 |
| C   | 38,870        | .....                  | 288,700 (B)           |
| D   | .....         | .....                  | .....                 |
| E   | 38,870        | 1,828,600 (B)          | .....                 |
| F   | 38,870        | 366,000 (B)            | 175,400 (B)           |
| G   | 38,870        | 393,900 (B)            | 845,500 (B)           |
| H   | 38,870        | 834,100 (B)            | 1,222,300 (B)         |

B signifies bar broke.

<sup>a</sup> Exact number uncertain.

## The Influence of Copper Upon the Physical Properties of Steel.

Discussion of the paper of G. Howell Clevenger and Bhupendranath Ray, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 82, October, 1913, pp. 2437 to 2475.

ALLERTON S. CUSHMAN,\* Washington, D. C.:—I am very much interested in the subject matter of this paper. I have had occasion to speak to this question before. There has recently been so much written and said and claimed about the effect produced by the addition of small quantities of copper to steel that there is certainly an impression abroad that a new and wonderful cure-all has been discovered. Are we facing a method of alchemy by which, at the expenditure of very little trouble and only a few cents' worth of copper per ton, the well-known characteristics of steel with respect to some features are so marvelously changed as in effect to produce a new metal? I am a great believer in the future of the iron and steel alloy field. I do not think that with all the advances we have made in metallurgy we have begun to scratch the possibilities of usefulness to mankind in the exploration of the alloy field, and I include in that alloy field even what might be designated as the dilute alloy field; that is to say, where a very small quantity of a metal alloyed with iron and steel confers upon it some new or extraordinary qualities. With respect to many of the physical characteristics of the copper-iron or copper-steel alloys I am not particularly competent to speak. With respect, however, to the investigation of corrosion problems and with respect to claims made with regard to resistance to corrosion, I am competent to speak insofar as I have specialized to some extent in that field and have given up a great deal of my time for a great many years to a study of it. Some years ago, being particularly interested in the study of corrosion problems, I received the very generous permission of a large manufacturing concern to use their large open-hearth furnaces any way I saw fit for exploring this particular field. There is not a metallurgist in this room who will not realize the generosity of a manufacturing company who would permit a man to pursue a theory and give him as his material to work with 60 tons of molten metal. At all events, I threw copper into the open-hearth furnace. I explored this alloy field, not in a little crucible in which I had to take out portions and have them

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\* Non-member.

poured out into test pieces, but 60 tons of each one of the alloys were manufactured, covering pretty thoroughly the range reported on by this paper. Each one of these heats was carefully watched throughout its heat treatment in the rolling mill until it was rolled down to the finished product, and following this a very elaborate series of weather-exposure tests was made. In addition, every possible laboratory test that has been proposed, including a number of original tests, was used in order to study the possible effect of copper in producing an extra corrosion resistivity in the metal. I had originally hoped that copper was going to prove to be a solution, or at least a partial solution, of the difficulty involved in manufacturing a metal of maximum resistance to corrosion at a reasonable cost. As time went on I was obliged to conclude as the result of many tests that copper was not beneficial to iron in aiding it to resist corrosion, but, on the contrary, was in many cases deleterious. In order to be conservative one has to admit that although copper may not be of any benefit to a comparatively pure iron base, it may, in some extraordinary way, either by preventing segregation of other impurities or for some other reason, be beneficial to steel. I am not prepared to prove that in some cases copper steel may not show an added resistance to corrosion, but I cannot say that the tests which I have under way seem to be tending toward that conclusion, and I greatly fear that the introduction of a certain small copper content as a standard of specification is going to admit improperly made steels, provided their copper content seems right. I am fortunate enough to have at my disposal a saw that in a reasonably short space of time will cut in two pieces longitudinally an iron or steel ingot 18 by 20 in., weighing about 5,000 lb. With this instrument at my command I have been interested in splitting open a number of ingots in order to study the best methods of getting dense, solid metal. Insofar as segregation influences the resistance to corrosion of the finished products, I think we must all admit that there may be two kinds of segregation: the one chemical and the other physical. For instance, in an ordinary steel, sulphide of manganese or a double carbide of manganese and iron may crystallize out of the molten magma during the cooling operation, and produce chemical segregation. Again, a molten metal on cooling may inclose gases and be full of blow-holes. If a material of this nature is rolled down to a finished sheet, it will suffer from this physical segregation or open condition of the ingot and be more or less laminated. Such a laminated material cannot be expected to be as slow rusting as one that is rolled from a dense, solid ingot. My observation so far, in the use of this apparatus, has

been that the copper metal appears very much worse from the standpoint of physical segregation than the commercially pure iron. It is apparent that the authors of this paper, who were working with small runs of the crucible steels, encountered the same difficulty, and in their summary they recommended the advisability, where copper steels are about to be made, of the use of special deoxidizers in order to overcome the tendency to make open ingots. They state: "In making copper steel by the crucible process it is necessary to 'kill' the metal before adding the copper, and just before pouring it is advisable to add a small amount of some deoxidizing agent." Of course, on the large scale of steel operation in the open-hearth plant, deoxidizing agents are invariably used and the metal is properly quieted.

I think it is now generally admitted that the rate at which a metal dissolves in acid is not a true measure of its corrosion resistance when it is put out under service. I have always thought that I was more liberal toward the acid test than a number of my colleagues, inasmuch as I have always claimed that it was a useful test if properly interpreted, even though it is not a true measure of atmospheric corrosion resistance. It will be noted (see table, p. 2445, and Fig. 5) that at first as the copper content rises in their experimental heats the solubility in acid goes down, but, having reached a minimum, it starts up again, and when it goes up it proceeds far beyond where it started from when there was no copper in the metal at all. I can think of no reason why adding successive increments of copper to successive heats should have this effect, unless electrolytic action begins to make itself more and more felt as the increase of copper and the tendency to segregation increases. I therefore interpret this curve as showing that copper dissolved in steel tends to segregate, and if this is true, this tendency has to be overcome by the manufacturers of copper steel or else electrolysis, with its well-known tendency to produce rapid and localized corrosion, will take place.

The question I am discussing is whether the use of copper as a preservative for steel is a move in the right direction. If we should grant that a copper steel properly made will last longer than a steel without copper in it, what guarantee is there in the purchase or use of copper steel that it is properly made and that neither chemical nor physical segregation will produce deleterious results? Speaking for myself, I can only say that if I had no other evidence but this theoretical consideration, I should be opposed to the widespread use of copper steel until the actual evidence came in to prove that it was superior in rust resistance to carefully made steels which did not

carry copper. I believe I may truly say that I have under my observation at the present time probably more extended atmospheric and other sorts of corrosion tests than any other investigator of this problem. I have been interested in it for a number of years, and I am anxious to get at the truth. If I can be convinced in the course of time that copper steel is more resistant to corrosion than any other form of ferrous metal I shall not hesitate to make the admission, but the results so far obtained on tests which I am constantly inspecting have pointed in quite the opposite direction. For instance, some time ago I caused to be built a large manure stack which was made of alternate slats of corrugated ungalvanized material, all of equal gauge. The slats were not allowed to touch each other, but had open spaces between them, through which the seepage from the manure could escape. Some of these slats are now beginning to go, and I have no hesitation in stating here that in this particular case the copper steels and copper irons were the first to give way. I am quite aware of the fact that it is impossible to discuss so important a subject as this without developing grave differences of opinion between colleagues. Separate investigators do not report results which agree with each other. This seems to be inevitable in the study of all sorts of problems in this world. There can be, after all, only one solution, and that is to patiently wait until sufficient time has gone by for the points at issue to be thoroughly tested out; but I cannot agree that the tests made by any one investigator, whether by myself or by anybody else, as the result of the observation of a few months or of a year, can be taken as conclusively settling an important problem in which so many different kinds of people are vitally interested.

ROBERT W. HUNT, Chicago, Ill.:—A matter has come under my attention within the last two weeks which is of interest to me, particularly as I think I have been somewhat of an old foggy in thinking that the way to make good steel is to make good steel. There is a pipe line company in the far West which is about to lay several hundred miles of pipe. They have taken out of an existing line some samples of pipe and submitted them for analysis, so that they might have specifications drawn to give them, if possible, exactly the same material and results, as the pipe had given such excellent service and had been in the ground a little over 30 years. The pipe was made in Wheeling, W. Va. Analysis disclosed that, so far as its chemical composition was concerned, it was very ordinary Bessemer steel. But 30 years takes you back to about the time that Frank Hearn started making steel pipe. It was just about the time that the atten-

tion of the people who were then making steel in this country was particularly directed toward making soft steel, and they endeavored to get good results by great care in the blowing of that metal, having the ingots sound, discarding anything that indicated segregation or porosity, and working it carefully and thoroughly; and I think the life of that pipe is explained in that way. I am going to try to find out if that is not some of Frank Hearn's original pipe. You may recall, Mr. Chairman, that he announced to the Institute the great results that he was accomplishing as against the then generally used iron pipe.



## Over-Oxidation of Steel.

Discussion of the paper of W. B. Shimer and F. O. Kichline, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 81, September, 1913, pp. 2361 to 2377.

ALLERTON S. CUSHMAN,\* Washington, D. C.:—I have been much interested in Mr. Shimer's valuable contribution. The apparent fact that the oxides of certain metals which are not reduced by hydrogen *per se*, are reducible when the oxides are dissolved in iron in small quantity, is brought out for the first time, and is worthy of the careful attention of investigators. The Ledebur method has been subjected to considerable criticism, owing to the alleged fact that it did not measure the oxygen combined with impurities. Personally I have found the method extremely helpful in spite of the minute quantities of oxygen with which it deals.

Mr. Shimer points out that the highest oxygen he obtained by over-blowing was 0.074 per cent., while the minimum quantity in a properly finished steel was in the neighborhood of 0.02 per cent. The Ledebur method is used as a constant check on the quality of heats made in practice under my direction. In dealing with a very pure commercial iron, we should expect to find and would find difficulty in galvanizing sheets made from a heat running 0.07 per cent. oxygen. In fact, we do not like to have the oxygen rise above 0.03 per cent.

I am inclined to agree with the author that excessive oxygen leaves a bath of metal in a very short time, but nevertheless I believe it takes only a very little combined oxygen to begin to make its presence felt in the pickling and galvanizing department, when sheet metal is the product manufactured. As Mr. Shimer points out, the higher the carbon, the lower the oxygen danger, and it is partly for this reason that the manufacture of carbon-free metal in the open-hearth furnace has to be so very carefully watched and controlled from the furnace through to the finished product. It is quite possible that there is a critical temperature of dissociation between iron and oxygen, although the critical points may vary in baths of different carbon content. Unfortunately, the accurate determination of the temperature of a molten bath at the time of pouring or teeming is a very difficult matter. For a long time I have been wishing that there were some reliable data which would indicate the effect of the tem-

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\* Non-member.

perature of the bath on the oxygen content. It is quite possible that at the highest temperature at which a heat is properly finished in the furnace, it is pretty thoroughly deoxidized, but that during the cooling which takes place while the pouring and teeming operations are going on oxygen begins to be taken up again.

We must not forget that iron is eager to combine with oxygen and will do so unless it is prevented, and, moreover, that we are working at the bottom of an atmospheric ocean consisting of one-fifth oxygen, and under a fairly constant pressure of 15 lb. to the square inch.

In the making of Bessemer and open-hearth steels under the usual conditions of practice and with the addition of recarburizers, I quite agree with Mr. Shimer that a metal running over 0.030 oxygen should not be encountered. In the manufacture of very pure iron in the open-hearth furnace, the matter is not so simple, and constant care and watchfulness are necessary. Even in this case, however, a heat finishing much over 0.05 per cent. in oxygen by the Ledebur method would not be considered to have been properly treated.

If an ordinary Kipp generator is used in the laboratory and mossy zinc is the source of the manufacture of the hydrogen, of course that mossy zinc goes into the Kipp generator full of air and therefore the oxygen included in the zinc will be gradually carried along with the hydrogen, and, going over the hot iron in the tube, would form water and bring in an error. If, however, the hydrogen is electrolytic hydrogen that is used in the analytical method and is carefully dried, then of course the preheating tube can be safely done away with.

J. E. JOHNSON, JR., New York, N. Y. :—If the Ledebur method, as used by Mr. Cushman, does not give the oxygen from any oxide except that of iron, then that fact is greatly in its favor. If we have a method which gives oxygen from whatever source, even slag, then we get a result which has no necessary connection with the fundamental quality of the metal, but only with the casual or accidental impurities which it contains, for a small quantity of slag will contain more oxygen than a very large quantity of steel.

We have other methods of finding slag and the oxides of other substances than iron, because they are not soluble, or at least only to a very slight degree, in the bath, whereas the oxide of iron is highly soluble in the bath and exercises a chemical influence on the character of the metal far more important than that exercised by particles of slag or other oxides undissolved.

I would like to confirm the statement of Mr. Cushman in regard to the importance of the preheating tube when using the Kipp hydro-

gen generator. At the Ashland plant of the Lake Superior Iron & Chemical Co., at which I was Manager for several years until recently, we made a great many determinations of oxygen and we found the preheating tube to be an absolute necessity.

There is a feature of this subject which appears to have been very generally overlooked. The affinity of carbon for oxygen rises very rapidly with the temperature, and for this reason a large quantity of carbon in the bath has a much smaller deoxidizing influence than a very small quantity of carbon at a high temperature.

I recently saw a Stoughton converter turned down when the silicon had been blown out and the metal still contained about 3 per cent. of carbon. That metal was what a furnaceman would call a wild white iron. It was bubbling actively in the converter and the metal when poured was full of blow-holes. It was evidently full of oxygen and the reaction between the oxygen and the carbon was still going on, although slowly. A similar heat blown until the carbon was down to 0.04 gave a metal as quiet and almost as free from bubbling as so much cream. It poured quietly and appeared to be absolutely free of oxygen before the addition of the deoxidizers. I am convinced from this and from the results of the experiments made by Mr. Shimer that the temperature of the bath is the principal element in controlling the amount of oxygen the bath will retain. If the temperature is high enough a very small amount of carbon remaining in the bath is sufficient to react with the oxygen and remove almost all of it; whereas, if you keep the temperature low a much larger quantity of carbon is entirely unable to accomplish this result. In my judgment, this is the reason, rather than any obscure or mysterious chemical phenomena, why the electric furnace will give a metal freer of oxygen than any other. These furnaces have at command an enormous temperature which they can maintain for an indefinite time in any sort of atmosphere that may be desired, and this high temperature enables them to cleanse the bath of oxygen as they could not do in any other way.

HENRY D. HIBBARD, Plainfield, N. J.—This serious attempt to chase elusive oxygen to his lair and find out how big he is and something of what he does there is most commendable and instructive. Some of the authors' interpretations of the phenomena observed may, however, be open to criticism. The word steel is used in the title and elsewhere in the paper when iron would perhaps be more correct, as it deals for the most part with oxygen in decarburized iron, which of course is not steel, but which forms a step in the manufacture of steel.

Determinations of oxygen in steels are indeed given, but only for comparison, not being made on over-oxidized steels. Every one now agrees that steel, to be steel, whatever other properties it has, must be usefully malleable or ductile.

Oxygen is the chief reagent used in the oxidation processes of making steel, being needed in the acid processes to oxidize and thereby eliminate carbon, silicon, and manganese from the stock, and in the basic processes phosphorus, and to some extent sulphur as well. To do so at a fair rate requires that an excess of oxygen be introduced to the molten charge. To make commercial steel demands that the excess at the end of the operation be decreased to a certain unknown content, which the determinations given in the paper fix at something under 0.02 per cent.; probably the less the better for the quality. The removal of this excess of oxygen, or the oxides it forms, is done partly by furnace treatment and partly by the addition of elements having, at steel-melting temperatures, greater affinity for oxygen than iron has. Chief of such elements is manganese. In every case enough time must also be allowed for the removal of the undesired excess of oxygen and its products. The determinations of oxygen by Walker and Patrick, by their vacuum method, indicate that the method used by the authors does not give the whole content of oxygen, but perhaps only that combined with iron. Indeed, on comparing the analyses of the blown irons with those given of finished steels it might be supposed that the difference between 0.019 and 0.029 per cent., or 0.01 per cent., of oxygen, was all there was to account for one being so red-short as to break in forging at the first blow of the hammer, while the other was of a commercial quality. It is hard to believe that such was the case.

Walker and Patrick always obtained much more oxygen by their vacuum method than by Ledebur's method, usually a number of times as much. Nevertheless, the paper under consideration is valuable in giving the comparative amounts of oxygen in iron blown in various ways and with subsequent additions of molten pig iron.

If we surely knew the total oxygen content of a steel or decarburized iron we then would need to know the proximate analyses or the compounds such oxygen formed, including oxides of manganese, silicon, and iron and their mixtures and derivatives. Knowing these, we would still need to know their modes of occurrence, concentration, and distribution in the steel and then how to interpret such modes, particularly in terms of physical properties.

In order to show the relations of the tests and results given in the paper to actual steel making, it would have helped greatly if the

usual amounts of manganese for the different grades of steel had been added and the resulting steels examined and tested. As it is, the effect of oxygen in steel is left unknown to nearly the same extent as before.

The recurrence of about 0.025 per cent. of oxygen in the tests which by reason of decreased blowing or additions of pig are less strongly oxidized than the others, raises the question as to whether or not there is a state of equilibrium when that amount is present.

The assumed probability in regard to test No. 9, that the sonim globules (solid non-metallic impurities) are iron phosphide, seems open to objection. The converter evidently had an acid lining, and if so no separation of phosphide would take place in the presence of an acid slag. The sonims in this test would appear more likely to be chiefly mixed silicates of manganese and iron, the silicon and manganese being derived chiefly from the added pig iron and being oxidized by a part of the oxide of iron contained in the over-blown metal. It would be interesting to know how the authors determined the gray centers of the ferrite bands in No. 9a to be phosphide of iron, and why they ascribe the red-shortness of Nos. 7, 9, 12, and 13 to that constituent when there is ample oxide and silicate present to cause it.

The manganese in some of the tests, notably in No. 10, is probably in the form of an oxide. This is practically proved by the fact that a 5 min. after-blow did not decrease the amount, which it must have done if it was in the metallic form, and also shows that there was little if any silica present to flux it, as practically all of that formed during the blow had presumably already entered the slag.

The forging capability of test No. 21 might perhaps have been due to its low content of oxygen, as low as that of some of the determinations given of oxygen in finished steels (0.017 per cent.), instead of absence of phosphide of iron, as the authors state. The 0.3 per cent. of manganese present was enough to prevent the presence of any large excess of oxygen in the blown metal and was clearly, it would seem, the cause of the good forging property.

HENRY M. HOWE, New York, N. Y.:—Mr. Hibbard, I believe, thinks that a dead man must not be spoken of as a man, and that over-blown metal must not be spoken of as steel. I do not know that I can accept that. There was the old idea very deeply rooted among very intelligent observers that if you once very badly over-oxidized metal you never could get it back so that it would be really very good metal. It would pass all common commercial tests, but never would be very good metal. Many of the things that have been

reported from the electric furnace would seem to indicate that that was a mistake, and that the reason you did not get good metal was that as the open-hearth furnace was actually constructed and operated, you did not have an opportunity to get the oxygen out. You could not pig back effectively, because the re-oxidation followed so fast on your de-oxidation. Very likely Mr. Acker can tell us how that is from his experiments. Having over-oxidized so very far, farther almost than any one else, was he then able to make really good steel out of it?

I should like to ask about the effect of temperature on the oxygen. If I understand Mr. Cushman, it is with falling temperature that the solubility of oxygen increases, in his opinion. It has been asserted that when you rabbled the bath and got enormous evolution of gas, that evolution was due to the lowering of the temperature by the cold rod, implying that lowering the temperature favored the removal of oxygen by forming CO. Is he really prepared to say that the evolution of gas on stirring is purely mechanical and is not due to the lowering of the temperature by the rod?

ALLERTON S. CUSHMAN: I think it will be seen that I merely raised a question in regard to the deoxidation of a metal bath in the open-hearth furnace. I had no intention of making any definite statement in regard to the subject. Most of my experience in iron metallurgy has been in connection with the development of pure commercial irons as made in the basic open-hearth furnace, which called for a bath several hundred degrees hotter than an ordinary steel bath, and the heat is kept on for a longer time. Certain things that have come under my observation have led me to question whether, under the conditions in which we are working, our metal is not more thoroughly deoxidized before tapping off than it is in the finished metal. It is quite possible that under the slightly reducing conditions of the open-hearth furnace and at a very high temperature, toward the end of the heat the superoxidized condition of the bath disappears and the metal is finished fairly well deoxidized, before any de-oxidizing agent has been added. In other words, I question whether, as a heat is conducted in the open-hearth furnace, a certain portion of it does not represent a superoxidation and another portion of it a subsequent reduction as the temperature rises. I believe this would be an interesting point to investigate in a systematic manner.

P. H. GRIFFIN, New York, N. Y.:—I would like to ask if any record has been made of the difference in oxygen content between the steel made at the present time and the steels which were made 15 or 20 years ago.

ALBERT SAUVEUR, Cambridge, Mass.:—We should be thankful for any information added to the little we really know regarding the presence of oxygen in steel, and we should be indebted to Mr. Shimer for his valuable contribution. It is, I think, surprising to note the slight difference in oxygen content between a normal heat and an excessively over-oxidized one; namely, 0.08 per cent. in the one case, and some 0.06 per cent. in the other, seeing that the first steel should be thoroughly malleable, and the latter, red-short. We have all been taught to believe that steel at a high temperature is readily oxidized, and still, according to Mr. Shimer, it will not take up more than 0.06 or 0.07 per cent. of oxygen. Surely the craving of the metal for oxygen is easily satisfied. Do chemists believe that they have an accurate analytical method for the determination of that element?

JOSEPH W. RICHARDS, South Bethlehem, Pa.:—When Professor Walker and Mr. Patrick gave a paper on the determination of total oxygen in steel before the International Congress of Applied Chemistry, in September, 1912, I thought that we had then arrived at the method which would be thenceforth used in all such investigations as this under discussion. I think this investigation must be regarded as incomplete, because the authors did not use the vacuum-furnace method for determining the total oxygen. I do not say that the Ledebur method should *not* be used, for it gives us some information. But it was absolutely determined by Walker and Patrick's tests that the steel which gave no oxygen by the Ledebur method gave oxygen by the electric vacuum-furnace method. Therefore, I think that any investigator at the present time who is looking for the oxygen in steel ought to use either the vacuum-furnace method or both methods. One method supplements the other, and each gives some information which the other does not give. But the proper one to use is necessarily the electric vacuum-furnace method, to give the total oxygen. There certainly appear to be some inconsistencies in the results, which I think would have been cleared up by having used both methods.

Some one has asked why the metal was not recarburized and finished. But at Bethlehem they are using the duplex process, which gave an opportunity of over-blowing this steel and then taking it to the open-hearth furnace, so that the heat was not lost. Otherwise, these tests would not have been made. There is no Bessemer plant that would have over-blown this steel this way if it was not to be subsequently treated and used in the open-hearth or electric furnace. That explains why the steel was not finished in the ordinary way and the manganese added to it.

As to the reduction of the oxide of chromium, we must recognize the fact that the oxides which are in the bath and which will separate out as the metal cools are not necessarily there as pure oxides. They are probably there as combinations with the oxide with iron. We have oxide of iron and oxide of chromium in chromite, a naturally occurring compound, and it is altogether probable that we have in the bath there not chromium oxide, but something analogous to chromite, and this combination of iron oxide with chromium would be more easily reducible than the pure oxide of chromium.

Mr. Johnson's remark that a bath in a small converter was boiling quietly, with all its carbon in after the silicon had gone out, is easily explained by the fact that that was an evidence that the carbon was performing deoxidation of the bath. That boiling was evidently due to the action of the carbon on the iron oxide and the escape of CO gas. That brings us back to the fundamental course of oxidation of the bath, and that is certainly that the iron is oxidized continuously in large quantity, and then we have simultaneously, or nearly so, deoxidation all the way through the blow.

A. S. CUSHMAN:—I cannot agree with Professor Richards in his recommendation that the Arsem furnace method for determining the oxygen is either necessary or desirable. It is true that the Arsem furnace method determines total oxygen; that is to say, not only such oxygen as may be combined with silicates and included slag, but also any oxygen that may be present combined with aluminum if aluminum has been carelessly used as a deoxidizer. This method also includes oxygen that may be combined with segregated manganese or any other oxide which may be present as an impurity. As the Arsem furnace does not enable us to distinguish what the oxygen it determines is combined with, I do not think it yields data of the slightest value. It seems to me that what the iron and steel makers want to know is the condition of the oxidation of their bath, quite irrespective of how much slag may be included in the metal. In my opinion, the Ledebur method is the only one that gives this particular information, as it confines itself to determining, in the main, the oxygen which is combined with iron and which, I take it, is a measure of the condition of the oxidation of the bath. If a given metal contains any considerable quantity of slag inclusion, the microscope will give the information not only qualitatively but to some extent quantitatively.

I have seen reason to think that the behavior of a given metal in the pickling operation depends to a very large degree upon its con-



dition of oxidation, and I therefore think that the Ledebur method gives the manufacturer better control of his product, as it helps him to decide whether his heat treatment in the furnace has been running normally and regularly. The success of the galvanizing operation depends very largely upon the success of the pickling operation, and therefore I for one like to know what the Ledebur oxygens are running in normal and standard practice, whereas the results of the Arsem furnace method I should not be able to interpret.

JOSEPH W. RICHARDS:—What we want is both methods. I think Mr. Cushman will agree with me that the included slag is of probably as much importance as the included iron oxide, when it comes to pickling and other questions, and we should know its amount also.

P. WEILLER,\* Perth Amboy, N. J.:—In manufacturing steel in the open-hearth process, or in any other, the steel bath is covered all the way through by a layer of slag containing a large amount of iron and oxide in solution.

We all know that iron oxide is soluble in metallic iron. It is obvious that the iron oxide formed in the steel-making process will divide between the slag and the bath. The amount of oxide in the finished steel bath will be dependent on the equilibrium between slag and steel bath; that is to say, the amount of oxygen in the metal will mostly depend upon the nature of the slag.

In the electric furnace process this idea is realized. In this process the reduction is completed in a very particular way. After using the ordinary reducing agents in lump form in the steel bath some finely ground ferro-silicon is thrown on the surface of the limy slag. This slag, being very stiff, does not allow the reducing agent to reach the metal bath. In this way all heavy metal oxides in the slag are reduced, the equilibrium is destroyed, a further portion of oxides is allowed to pass from the metal bath to the slag and is in turn reduced, and so on until all the oxide is reduced and the slag is perfectly white. In this way a nearly perfect reduction can be obtained.

The amount of oxygen being dependent on the equilibrium between slag and metal bath, it is easily understood that this equilibrium will be greatly influenced by the temperature and by the composition of both metal and slag.

The only way to investigate what is called the over-oxidation of steel is to study the iron oxide-iron diagram and determine the equilibrium between slag and iron bath.

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\* Non-member.

MESSRS. SHIMER AND KICHLIN (communication to the Secretary\*):—Dr. Cushman's valuable discussion throws additional light on the subject under investigation. It is gratifying to the authors to know that their results are corroborated by the experience of this authority. No doubt the use of a preheating tube with the Kipp generator is an excellent precaution in a general sense. The authors used the preheating tube for a time, and then discontinued its use because it was found that the blank determination, after discarding the preheating tube, was not higher than before. We obtained 0.0003 to 0.0006 g. increase in weight as a blank, which was deemed entirely satisfactory. Blanks were run at the beginning of each day's work, so that if the generator was giving an impure hydrogen it would be detected immediately.

We can hardly accept Mr. Johnson's remark, that the hot metal, after the silicon has been taken out, containing about 3 per cent. of carbon, can be full of oxides, as they would immediately be taken up by this carbon at the high temperature of the metal at that period. His statement that the bath of metal containing 3 per cent. of carbon was "full of oxygen" gives us no conception as to the probable percentage he has in mind. In the strictest sense of the word the term "full of oxygen" would mean all that the bath would hold, which, of course, is correct, but from our investigation we have found it to be a comparatively low figure. When a Bessemer heat is at the point of 3 per cent. carbon there is quite an appreciable amount of manganese present, and this alone, even if carbon were not combining with the oxygen, is sufficient to eliminate the oxygen of the bath almost instantly.

Mr. Hibbard seems to believe that the difference in the forging qualities between tests Nos. 9 and 21 is due to the slight difference between the percentages of oxygen in them, 0.029 and 0.017 per cent. respectively. It will be recalled that test No. 9 contained 0.43 per cent. of carbon and about 0.450 per cent. of phosphorus, while test No. 21 was made of iron containing 0.120 per cent. of phosphorus. Therefore the reason for No. 9 being red-short and breaking in forging and No. 21 forging readily, can hardly be ascribed to the difference in oxygen content, the main difference being in the phosphorus content of the two tests. Test No. 8, from the same heat as No. 9, contained 0.064 per cent. of oxygen and only 0.03 per cent. of carbon and forged readily. That the combination of high carbon (0.430 per cent.) and high phosphorus (0.450 per cent.) in the above

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\* Received Nov. 13, 1913.

test caused it to be red-short is quite evident; the oxygen content was only 0.029 per cent.

The samples containing iron phosphide in the ferrite boundaries were etched with cupric chloride and that part making up the dark centers in the ferrite network turned black. This, together with Stead's test for iron phosphide (heat tinting), shows it to be iron phosphide. That they are not sonims (non-metallic impurities) we are certain, or they would have been discovered on the polished surfaces before etching. The heat showing the greatest amount of "sonims" under the microscope was Heat *G*, with a skull in the vessel, which was determined and found to contain 0.058 per cent. of slag inclusions (sonims), while the iron phosphide content of this same metal runs from 2.90 to 3.10 per cent. The quantitative estimation of the dark elongated centers in the ferrite network, with the microscope, agrees with the percentage of iron phosphide rather than with the percentage of slag inclusions, which is so strikingly less in amount. The oxygen contents in the tests which were red-short are considerably lower than those in the tests which forged readily.

With regard to the nature of the *round* spots in the unetched test No. 9: as this was the only test containing spots of this nature, we merely called attention to them as differing from the regular oxide pits. Since they had no connection with the subject of our paper, we spent no time trying to learn their identity. We assumed that they probably were iron phosphide (out of solution), but we are not prepared to say so definitely and are quite willing to agree with Mr. Hibbard that they might be manganese silicate.

We were not investigating the physical effect of oxygen in steel, but wanted to learn to what extent oxygen could be retained in the steel after every effort was made to over-oxidize it. We endeavored to show, from our results, that this over-oxidation is very difficult and that in the usual process of making steel there is not much need to fear it, because the oxygen so quickly leaves the bath, and the amount retained by the steel seems to be well within safe limits.

We are glad to advise Mr. Griffin that it has been our good fortune to find a sample of old Bessemer rail steel, made about 20 years ago, which gave the following analysis: C, 0.600; Mn, 1.07; P, 0.060; S, 0.070; Si, 0.069; oxygen, 0.024 per cent.

While the determination of total oxygen by the Walker and Patrick method, suggested as desirable by Dr. J. W. Richards, would no doubt have a certain interest, we cannot help thinking that the results by the Ledebur-Cushman method give us much more nearly

the exact information that we desire. This method, moreover, has been in successful use in many laboratories long enough to make it trustworthy, which perhaps is more than can at present be said of the vacuum method.

The statement of Dr. Weiller that the slag covering the steel bath contains a large amount of iron oxide, and that "the amount of oxygen in the metal will mostly depend upon the nature of the slag," does not agree with the results of our investigation. We have had to do with both acid and basic slags of both high and low content of iron oxide, all of which gave a low oxygen content in the steel. For example, in acid Bessemer heats, the usual content of iron oxide in the slag was from 10.50 to 11.00 per cent., with oxygen 0.030 per cent. or under in the steel, while one test (No. 17), with 0.029 per cent. of oxygen, was covered with a slag of 22 per cent. iron oxide. Test No. 19, with 0.033 per cent. of oxygen, had a slag of 34 per cent. iron oxide, and Test No. 15, with 0.017 per cent. of oxygen, had a slag consisting almost entirely of molten iron ore, with a small amount of Bessemer slag which inadvertently ran into the ladle. As to basic open-hearth practice, we have had, since our paper has gone to press, heats with slags whose iron oxide content varied from 10 to 25 per cent. (other elements remaining the same excepting silica), but the oxygen content of the steel was always around 0.020 per cent. This proves that the oxide content of the slag has no bearing on the oxygen content of the steel.

We have a private communication from Sir Robert A. Hadfield containing the following paragraph:

"Your conclusions largely confirm my own, that those statements in the past, where it has been mentioned that quite a considerable percentage of oxygen has been found in material, have been incorrect."

## The Cleaning of Blast-Furnace Gas.

Discussion of the paper of W. A. Forbes, presented at the New York Meeting, October, 1913, and printed in *Bulletin* No. 82, October, 1913, pp. 2477 to 2514.

SAMUEL K. VARNES,\* Steelton, Pa. :—We have a gas-cleaning plant consisting of a centrifugal dry dust catcher, and two rain-type wet scrubbing towers, 25 by 60 ft. each, for rough cleaning of blast-furnace gas. This plant was put in early in 1910, with the intention of cleaning gas for use in hot-blast stoves and under boilers, and was so used for several months. Soon after it went into service, the blast-furnace men complained that they could not get as high blast temperatures as they had obtained when using dirty gas. It was decided to run a series of careful tests to determine if this were true and to what degree the apparent results might be affected by other conditions. About 60 tests were run, covering a period of five months, and at the end we came to the conclusion that it did not pay us to scrub the gas for stoves and boilers. The tests were all run upon a single stove, no boiler tests being made, but the conclusions of the stove tests being applied to the boilers.

The furnace burden was practically the same for all the tests and averaged :

|                                  | Per Cent. |
|----------------------------------|-----------|
| Daquari and other hard ores..... | 57        |
| Nodules.....                     | 13        |
| Raw Mayari ore.....              | 25        |
| Mill cinder and scale.....       | 5         |

The raw Mayari is exceedingly fine, and produces even more flue dirt than does the fine Mesabi ore. The average results of these tests are here shown :

|                                                             | Wet Scrubbed<br>or Clean Gas. | Dry Cleaned<br>or Dirty Gas. |
|-------------------------------------------------------------|-------------------------------|------------------------------|
| Grains of dust per cubic foot.....                          | 0.8                           | 2 to 3                       |
| Moisture in gas, pounds of water per pound of dry gas.....  | 0.035                         | 0.05                         |
| Temperature of gas at burner.....                           | 100° F.                       | 300° F.                      |
| Temperature of stack gas.....                               | 450° F.                       | 500° F.                      |
| Temperature increase of blast in passing through stove..... | 925° F.                       | 1,050° F.                    |

The moisture content of the clean gas is seen to be only 70 per cent. of that of the dirty gas, hence the gas was partly dried by wet cleaning. By "temperature increase of blast in passing through stove" is meant the difference between the temperature of the blast on leav-

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\* Non-member.

ing and on entering the stove. The dirty gas shows 125° higher blast temperature. The maximum increase of temperature in case of the clean gas was 962° F., or less than the average of the dirty gas.

We found further that the efficiency of the stove and burner as a regenerator was higher by about 1 per cent., using dirty gas. The values of these efficiencies are not absolute but relative only, having been determined by the heat-balance method after calculating radiation and convection losses from the shell. Having determined that we got higher efficiencies and higher blast temperatures with dirty gas, and being able to keep a stove in service during a furnace run of three years without stopping to clean it, we could see no reason for continuing to wash gas for stoves, and the practice was accordingly abandoned early in 1911. The scrubbing plant is now used for preliminary washing for the Theisen final washer on gas-engine service.

A. N. DIEHL, Duquesne, Pa. :—We have listened with great pleasure to Mr. Forbes's interesting paper, which has outlined the most prominent methods so far developed in blast-furnace gas cleaning. As he has plainly outlined, there are the two distinct systems, wet and dry cleaning, and also what are termed primary and secondary in the wet method. The primary includes scrubbing or such cleaning as is necessary to fit the gas for stove and boiler use; the secondary, that which further wet cleans the gas sufficiently for engine purposes. In the dry system, the gas may be cleaned by centrifugal action and by filtration. The quantity of gas issuing from a blast furnace is about 150,000 cu. ft. per ton of iron, and varies, with the coke consumption, in combustibles, therefore in thermal capacity. The average temperature of the gas is about 400° F., and it contains varying quantities of dust, depending on the velocity of the gas passing through the stock, the physical condition of the stock, and the working condition of the furnace. Attempts have been made to prevent the dust, so mechanically carried, from being expelled from the furnace stack, by such construction of the gas flues that the material carried up by irregular movements of the furnace will fall back into the furnace instead of going down the downcomer flues to the dust catcher. An arrangement like this will also allow more air to be blown with less metallic loss, even under normal movement of the stock. With the use of 48,000 to 50,000 cu. ft. of air on a furnace with a 16-ft. stock line, the velocity of the gas is sufficient to raise even the heavier particles on the surface of the stock, and keep them in a state of constant vertical oscillation, making their expulsion comparatively easy with

any increase of velocity due to slight stock movements, or, if the out-takes are low, the velocity of gas may lead to a continuous stream of dust going over into the downcomer pipe. It is often noticeable that particles of coke, the size of a walnut, are expelled from the bleeders without a gas coloration on hard-blown furnaces. It has been our experience, on a furnace having four gas out-takes just above the stock line, that the increase of 2,000 cu. ft. of blast per minute above 50,000 will nearly double the loss in flue dust with no perceptible change in the working condition. This condition has been experienced during a number of attempts to increase the output and places a restriction on the quantity of air permissible; and furthermore, this actual experience justifies the foregoing explanation. It is thus evident that the gas carries material of all sizes, from the very finest in the normally blown furnace to large lumps expelled by slips. The dust catcher will serve to remove the very coarsest material and also that which is too heavy for the gas velocity to take with it, unless the dust is trapped. It is very often the case that dust sufficiently heavy to be deposited under normal velocities is picked up and carried forward by a sudden velocity increase due to opening bells or slips. The quantity of dust from a hard-slipping modern furnace to a normal one may vary from 500,000 lb. or more to 5,000 to 10,000 lb. per day, and it is evident that the quantity of dust per cubic foot of gas varies therefore over a great range.

There are three general types of primary wet washers: 1, the impinging washer; 2, the mechanical washer; 3, towers or scrubbers.

1. The impinging washer depends on directing the gas against a surface of water, the velocity imparted to the dust particles being sufficiently great to impel them into the water while the gas changes direction and goes on. These systems remove the heavier material, but expose the hot gas to the danger of becoming so moisture laden as to cause very inefficient combustion in subsequent operations unless the water be removed by further cooling.

2. Mechanical washers are generally dependent on a high-speed, motor-driven rotor revolving in a shell and having water injected in various ways. The water is broken up into a finely divided condition, and thus brought in intimate contact with the gas, being either "beaten" together or thrown together by centrifugal force, the water and sludge then flowing away. While these methods in many cases are successful in cleaning the gas, yet the capacities are low and the cost in installation, maintenance, and power is high.

3. Tower washers or scrubbers may be further subdivided as fol-

lows: (a) Those having the gas as the dominating element; (b) those having the water as the dominating element.

(a) In the first type the water is introduced at the top of the apparatus through nozzles and allowed to fall by gravity over baffles, or wooden grids, or in the form of rain. The gas, rising through the tower, comes in contact with the descending water and the wetted surface and thus becomes cooled and cleaned. These scrubbers depend on very low velocity of gas. If the velocity head is sufficiently high to deflect the water from its vertical course, the gas will pass up in a column through the path of least resistance, and thus prevent intimate contact. In these cases the velocity of gas determines the efficiency of the scrubber. Baffles and grids have been successfully used for increasing the efficiency, in different installations, and allow a high gas velocity to be handled, corresponding to the number of obstructions. These baffles in turn mean less gas-cleaning capacity per unit and higher resistance, which lowers the gas pressure accordingly. Another disadvantage of complicated construction within the tower is the tendency of the dirt to build up on any projection unless large quantities of water are used.

(b) Those having water as the dominating element depend on the higher pressure and velocity of the water to prevent the gas channeling. The water is introduced through vertical nozzles, turned upward, and the flow intermittently or successively cut off one nozzle. When the flow ceases an area directly above that nozzle becomes quiescent and the gas is driven to this point by the water flowing in the others. The water passing through the nozzle then resumes, driving the gas over the next nozzle, which is cut off in turn. This is repeated until the gas is beyond the range of the nozzles. The water has a tendency, therefore, to drive the gas from one point to another, the gas being sprayed as at the same time it rises in the tower. Thus the gas is being forced in an upward spiral path, being guided and deflected over each nozzle by the velocity and pressure of the water. Screens are used over the nozzles to atomize the water. Fig. 9 in Mr. Forbes's paper shows very clearly the action of this scrubber. The dirty water carrying away the dust passes from the base of the tower by means of a siphon arrangement.

*Clean Gas vs. Dirty Gas on Stoves.*—In first grasping the problem of cleaning gas, it must be determined for what purposes the gas will be used. If the gas is only to be used for internal-combustion engines, then efficiency in primary cleaning may not be so necessary, as the final cleaners can assume some of the work which should be done in the first stage. If, on the other hand, the gas is to be divided



after the first stage, part to stoves and boilers and part to the secondary cleaners, then the best efficiency should be gotten from the primary system. As before mentioned, the average temperature of gas from the top of the blast furnace will be about  $400^{\circ}\text{F.}$ , and probably  $350^{\circ}$  at the stove burners or scrubbers, or wherever it is sent. With Mesabi ores the moisture content of this gas will be about 85 grains of water per cubic foot of gas, calculated at  $62^{\circ}$ . In one case the gas is burned raw, containing 8 grains of dust per cubic foot, and in the other it is returned to the stoves and boilers at  $70^{\circ}$ , saturated with 7.98 grains of water and 0.2 grain of dust per cubic foot. The thermal table below will show the heat balances in these cases and also where the gas is returned from scrubbers to stove at  $125^{\circ}$ , saturated in regard to moisture, as in the case of inefficient or partial washing.

Inspection of this table will disclose the fact that, per pound of dry fuel gas consumed, clean gas at  $70^{\circ}\text{F.}$ , moisture saturated at  $70^{\circ}\text{F.}$ , gives an available heat of 79.51 per cent., products of combustion cooled to  $600^{\circ}\text{F.}$  Raw gas at  $400^{\circ}\text{F.}$  and 85 grains moisture follows with available heat of 77.03 per cent., products of combustion cooled to  $600^{\circ}\text{F.}$  Partly washed and cooled gas at  $125^{\circ}\text{F.}$ , moisture saturated at  $125^{\circ}$ , gives an available heat supply of 74.33 per cent., products of combustion cooled to  $600^{\circ}\text{F.}$

From a calculated thermal standpoint, we conclude, as evidenced by the table under inspection, that washed gas cooled to  $70^{\circ}\text{F.}$  gives the largest percentage of available heat. This is followed by hot unwashed gas under furnace-top conditions carrying 85 grains moisture. The lowest percentage of available heat is shown to exist for washed gas cooled to  $125^{\circ}$ . Under conditions of this table it may be interesting to note that thermal equilibrium, raw unwashed gas against washed gas, approximates a temperature midway of  $70^{\circ}$  and  $125^{\circ}\text{F.}$

*Heat Available per Pound of Dry Blast-Furnace Gas Under Various Conditions of Initial Temperature and Moisture Content. Combustion Air Constant Condition.*

| TOTAL HEAT EXPENDED ABOVE 32° F.                                  |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|-------------------------------------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| FUEL GAS.                                                         |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
| Sensible heat in dry fuel gas, B.t.u.....                         | 9.128     | 9.128     | 9.128     | 22.449    | 22.449    | 22.449    | 99.61     | 99.61     | 99.61     | 99.61     | 99.61     | 99.61     | 99.61     | 99.61     |
| Sensible and latent heat in moisture, B.t.u.....                  | 16.682    | 16.682    | 16.682    | 94.420    | 94.420    | 94.420    | 81.27     | 81.27     | 81.27     | 81.27     | 81.27     | 81.27     | 81.27     | 81.27     |
| Latent heat of combustion, 1 lb. dry fuel gas, B.t.u.....         | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 | 1,253.800 |
| Total, B.t.u.....                                                 | 1,279.610 | 1,279.610 | 1,279.610 | 1,380.669 | 1,380.669 | 1,380.669 | 1,434.68  | 1,434.68  | 1,434.68  | 1,434.68  | 1,434.68  | 1,434.68  | 1,434.68  | 1,434.68  |
| COMBUSTION AIR.                                                   |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
| Sensible heat in dry air, B.t.u.....                              | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     | 6.292     |
| Sensible and latent heat in moisture, B.t.u.....                  | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     | 7.729     |
| Total, B.t.u.....                                                 | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    | 14.021    |
| Total heat expended, B.t.u.....                                   | 1,293.630 | 1,293.630 | 1,293.630 | 1,394.69  | 1,394.69  | 1,394.69  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  |
| TOTAL HEAT IN PRODUCTS OF COMBUSTION AT 32° F.                    |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
| Sensible heat in dry products of combustion, B.t.u.....           | 144.65    | 183.14    | 228.69    | 144.65    | 183.14    | 228.69    | 144.65    | 183.14    | 144.65    | 183.14    | 228.65    | 144.65    | 183.14    | 228.65    |
| Sensible and latent heat in moisture, B.t.u.....                  | 81.41     | 38.89     | 36.87     | 117.24    | 128.12    | 129.24    | 94.16     | 99.07     | 94.16     | 99.07     | 104.08    | 94.16     | 99.07     | 104.08    |
| Total heat in products of combustion, B.t.u.....                  | 176.06    | 217.08    | 265.06    | 261.89    | 306.26    | 357.93    | 238.81    | 282.21    | 238.81    | 282.21    | 332.77    | 238.81    | 282.21    | 332.77    |
| HEAT BALANCE.                                                     |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
| Total heat expended, B.t.u.....                                   | 1,293.630 | 1,293.630 | 1,293.630 | 1,394.69  | 1,394.69  | 1,394.69  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  | 1,448.70  |
| Total heat lost in products of combustion, B.t.u.....             | 176.06    | 217.08    | 265.06    | 261.89    | 306.26    | 357.93    | 238.81    | 282.21    | 238.81    | 282.21    | 332.77    | 238.81    | 282.21    | 332.77    |
| Total heat available per lb. dry fuel gas consumed, B.t.u.....    | 1,117.57  | 1,076.60  | 1,028.57  | 1,132.80  | 1,088.43  | 1,036.76  | 1,209.89  | 1,166.49  | 1,209.89  | 1,166.49  | 1,115.93  | 1,209.89  | 1,166.49  | 1,115.93  |
| Total heat available per lb. dry fuel gas consumed, per cent..... | 96.89     | 83.23     | 79.51     | 81.22     | 78.04     | 74.38     | 85.52     | 80.31     | 85.52     | 80.31     | 77.08     | 85.52     | 80.31     | 77.08     |
| Total heat dissipated in products of combustion, per cent.....    | 13.61     | 16.77     | 20.49     | 18.78     | 21.96     | 25.67     | 16.48     | 19.69     | 16.48     | 19.69     | 22.92     | 16.48     | 19.69     | 22.92     |

*Comparison of Stove Tests.*

| Data.                                                       | Three-Pass<br>Central Com-<br>bustion Cham-<br>ber. Clean Gas. | Two-Pass<br>Central Com-<br>bustion Cham-<br>ber. Clean Gas. | Two-Pass<br>Central Com-<br>bustion Cham-<br>ber. Dirty Gas. |
|-------------------------------------------------------------|----------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|
| 1 Date of test.....                                         | 6/11/09                                                        | 8/19/09                                                      | 8/27/09                                                      |
| 2 Furnace and stove number.....                             | 5 F, 1 S                                                       | 4 F, 1 S                                                     | 2 F, 3 S                                                     |
| 3 Size of stove, ft.....                                    | 22 by 100                                                      | 21 by 96                                                     | 21 by 96                                                     |
| 4 Area of combustion chamber, sq. ft.....                   | 25.78                                                          | 28.47                                                        | 28.27                                                        |
| 5 Area of flues, first pass, sq. ft.....                    | 78.25                                                          |                                                              |                                                              |
| 6 Area of flues, second pass, sq. ft.....                   | 36.52                                                          |                                                              |                                                              |
| 7 Area of flues, checkers, sq. ft.....                      |                                                                | 77.91                                                        | 77.91                                                        |
| 8 Total heating surface, sq. ft.....                        | 49,865                                                         | 39,220                                                       | 39,220                                                       |
| 9 Cubic contents, cu. ft.....                               | 20,831                                                         | 17,974                                                       | 17,974                                                       |
| 10 Equivalent of 9 in. brick.....                           | 360,000                                                        | 135,560                                                      | 135,560                                                      |
| 11 Ratio heating surface to cubic contents.....             | 2.39                                                           | 2.18                                                         | 2.18                                                         |
| <i>Pressures.</i>                                           |                                                                |                                                              |                                                              |
| 12 Gas in main, in. water.....                              | 1.50                                                           | 1.50                                                         | 8.00                                                         |
| 13 Gas in burner, in. water.....                            | 0.82                                                           | 0.54                                                         | 3.77                                                         |
| 14 Pitot tube, in. water.....                               | 0.122                                                          | 0.055                                                        | 0.1085                                                       |
| 15 Draft at chimney valve, in. water.....                   | 0.41                                                           | 0.50                                                         | 1.66                                                         |
| 16 Blast pressure, pounds.....                              | 16.1                                                           | 15.4                                                         | 16.96                                                        |
| 17 Barometer, in. mercury.....                              | 29.32                                                          | 29.17                                                        | 29.36                                                        |
| <i>Temperatures.</i>                                        |                                                                |                                                              |                                                              |
| 18 Furnace gas at burners, ° F.....                         | 86.6                                                           | 88.9                                                         | 300.2                                                        |
| 19 Atmosphere, ° F.....                                     | 72.5                                                           | 74.0                                                         | 96.6                                                         |
| 20 Cold blast, ° F.....                                     | 152.8                                                          | 191.7                                                        | 227.0                                                        |
| 21 Hot blast—maximum, ° F.....                              | 1,600                                                          | 1,310                                                        | 1,425                                                        |
| 22 Hot blast—minimum, ° F.....                              | 1,360                                                          | 970                                                          | 1,000                                                        |
| 23 Hot blast—average, ° F.....                              | 1,462                                                          | 1,076                                                        | 1,148                                                        |
| 24 Chimney—maximum, ° F.....                                | 720                                                            | 680                                                          | 930                                                          |
| 25 Chimney—minimum, ° F.....                                | 565                                                            | 485                                                          | 600                                                          |
| 26 Chimney—average, ° F.....                                | 670                                                            | 612                                                          | 813                                                          |
| 27 Engine room—dry bulb, ° F.....                           | 89.5                                                           | 96.0                                                         | 102.0                                                        |
| 28 Engine room—wet bulb, ° F.....                           | 72.5                                                           | 79.0                                                         | 87.0                                                         |
| <i>Duration.</i>                                            |                                                                |                                                              |                                                              |
| 29 Stoves on gas, minutes.....                              | 179.0                                                          | 198.75                                                       | 148.75                                                       |
| 30 Stoves on blast, minutes.....                            | 60.0                                                           | 64.0                                                         | 50.5                                                         |
| <i>Gas.</i>                                                 |                                                                |                                                              |                                                              |
| 31 Heat per cu. ft. at 62° F., B.t.u.....                   | 105.8                                                          | 94.8                                                         | 99.4                                                         |
| 32 Total gas at tempt. and press. at burner, cu. ft.....    | 867,076                                                        | 693,439                                                      | 821,669                                                      |
| 33 Total gas at 62° F. and 30 in. mercury, cu. ft.....      | 810,333                                                        | 631,963                                                      | 679,827                                                      |
| 34 Gas per min. at tempt. and press. at burner, cu. ft..... | 4,844                                                          | 5,659                                                        | 5,756                                                        |
| 35 Gas per min. at 62° F. and 30 in. mercury.....           | 4,527                                                          | 3,489                                                        | 3,898                                                        |
| 36 Analysis of gas by vol.—carbon dioxide, per cent.....    | 15.90                                                          | 13.06                                                        | 12.40                                                        |
| carbon monoxide, per cent.....                              | 25.00                                                          | 25.78                                                        | 25.40                                                        |
| methane, per cent.....                                      | 1.20                                                           | 0.00                                                         | 0.00                                                         |
| hydrogen, per cent.....                                     | 4.20                                                           | 3.69                                                         | 5.80                                                         |
| nitrogen, per cent.....                                     | 53.70                                                          | 57.47                                                        | 56.40                                                        |
| 37 Moisture per cu. ft. of gas, grains.....                 | 13.53                                                          | 14.79                                                        | 20.59                                                        |
| 38 Analysis of chimney gas—carbon dioxide, per cent.....    | 24.39                                                          | 21.50                                                        | 22.70                                                        |
| oxygen, per cent.....                                       | 1.18                                                           | 2.90                                                         | 0.00                                                         |
| carbon monoxide, p. cent.....                               | 0.12                                                           | 0.80                                                         | 0.60                                                         |
| nitrogen, per cent.....                                     | 74.31                                                          | 75.00                                                        | 76.70                                                        |
| 39 Air excess coefficient.....                              | 1.20                                                           | 1.08                                                         | —0.993                                                       |

*Comparison of Stove Tests.—[Continued.]*

| Data.                                                      | Three-Pass<br>Central Com-<br>bustion Cham-<br>ber. Clean Gas. | Two-Pass<br>Central Com-<br>bustion Cham-<br>ber. Clean Gas. | Two-Pass<br>Central Com-<br>bustion Cham-<br>ber. Dirty Gas. |
|------------------------------------------------------------|----------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|
| <i>Blast.</i>                                              |                                                                |                                                              |                                                              |
| 40 Air blown per min. at eng. room temp., cu. ft.....      | 38,518                                                         | 44,460                                                       | 42,671                                                       |
| 41 Grains moisture per cu. ft.....                         | 6.42                                                           | 8.66                                                         | 8.48                                                         |
| 42 Air blown per min. at 62° F., cu. ft.....               | 35,742                                                         | 40,580                                                       | 38,780                                                       |
| 43 Total dry air blown, pounds.....                        | 163,836                                                        | 172,959                                                      | 144,993                                                      |
| 44 Total moisture blown, pounds.....                       | 2,124                                                          | 3,170                                                        | 2,613                                                        |
| <i>Heat.</i>                                               |                                                                |                                                              |                                                              |
| 45 Total heat absorbed, B.t.u.....                         | 52,756,822                                                     | 37,665,082                                                   | 32,834,652                                                   |
| 46 Total heat expended, B.t.u.....                         | 65,733,124                                                     | 58,404,422                                                   | 57,364,504                                                   |
| 47 Efficiency, per cent.....                               | 62.24                                                          | 64.40                                                        | 56.97                                                        |
| <i>Working Conditions.</i>                                 |                                                                |                                                              |                                                              |
| 48 Time stove in service since last cleaned, mos.-das..... | 2-29                                                           | 7-19                                                         | 1-14                                                         |
| 49 Burner opening, inches, .....                           | 0                                                              | Full.                                                        | 5                                                            |
| 50 Cleaning door, inches.....                              | 0                                                              | 3                                                            | 3                                                            |
| 51 Blow off valve open, turns.....                         | 4                                                              | 0                                                            | 0                                                            |
| 52 Piston displacement, per cent.....                      | 92.50                                                          | 91.27                                                        | 90.88                                                        |
| <i>Heat Balance.</i>                                       |                                                                |                                                              |                                                              |
| 53 Heat absorbed by blast, per cent.....                   | 62.24                                                          | 64.48                                                        | 56.97                                                        |
| 54 Heat lost in flue gases, per cent.....                  | 17.40                                                          | 19.28                                                        | 24.95                                                        |
| 55 Heat lost due to incomplete combustion, per cent....    | 0.53                                                           | 4.52                                                         | 2.85                                                         |
| 56 Heat lost hydrogen, per cent.....                       | 3.48                                                           | 2.36                                                         | 3.36                                                         |
| 57 Heat lost by moisture in fuel gas, per cent.....        | 0.45                                                           | 0.58                                                         | 1.48                                                         |
| 58 Radiation, unaccounted for, etc., per cent.....         | 15.90                                                          | 6.78                                                         | 10.39                                                        |
| 59 Efficiency of burner, per cent.....                     | 99.47                                                          | 95.48                                                        | 97.15                                                        |
| 60 True thermal efficiency, per cent.....                  | 62.57                                                          | 67.53                                                        | 58.64                                                        |

NOTE.—Item No. 60, 54/60.

The data tabulated below form the basis for the comparative table following, and are averages of our condition during 1909. The reports of boiler and stove tests are records made within a year. No assumptions have been made unless noted.

|                                                 |                 |
|-------------------------------------------------|-----------------|
| Average tonnage basic iron per day.....         | 443 tons.       |
| Coke per ton iron.....                          | 2,256 lb.       |
| Limestone per ton iron.....                     | 1,118 lb.       |
| Wind blown per lb. coke.....                    | 60.82           |
| Gas per ton iron.....                           | 12,000 lb.      |
| Gas at 62° per ton iron.....                    | 156,000 cu. ft. |
| Gas at 62° used at stoves, per minute.....      | 4,170           |
| Gas at 62° used at boilers.....                 | 33,010          |
| Heat per cu. ft. furnace gas at 62°.....        | 93.9 B.t.u.     |
| Average efficiency stoves on rough gas.....     | 56 per cent.    |
| Average efficiency stoves on clean gas.....     | 64              |
| Average efficiency boilers on rough gas.....    | 56              |
| Average efficiency boilers on clean gas.....    | 62              |
| Force required to clean stoves per furnace..... | 2               |
| Wages for same.....                             | \$3.91          |
| Force required to clean boilers per turn.....   | 1 per turn.     |
| Wages for same.....                             | \$2.04          |
| Force required at scrubbers.....                | 1 per turn.     |
| Wages for same.....                             | \$2.50          |

#### *Heat Value of Coke at Tuyeres.*

$4,450 \times 0.8411 = 3,743$  B.t.u. Heat available per pound coke burned to CO at tuyeres. (Average carbon in coke during 1909.)

$3,743 \times 0.84 = 3,144$  B.t.u. Equivalent in coke of heat increment in hot blast. (Percentage coke burned at tuyeres.)

#### *Average Weight Blast per Ton Iron.*

7 grains moisture. Average engine room temperature, 90°.

$7.000 \div 7000 = 0.001000$  Weight moisture per cu. ft. air.

$0.00100 \times 26.36 = 0.02633$  Volume moisture per cu. ft. (uncorrected).

$0.02636 \times \frac{459 + 90}{459 + 212} = 0.02157$  Actual volume moisture.

$0.0761 \times \frac{459 + 62}{459 + 90} = 0.07222$  Weight dry air per cu. ft. at 90° F.

$0.0761 \times 0.0784 = 0.07066$  Weight dry air actually present.  
0.00100 Weight moisture actually present.

0.07166 Weight air blown per cu. ft. at 62° F.

$2,256 \times 60.82 = 137,164$  cu. ft. air blown per ton iron.

$137,164 \times 0.07166 = 9,829$  Weight moisture air blown.

$9,829 \times 0.98605 = 9,692$  lb. dry air blown per ton iron.

$9,829 \times 0.01395 = 137$  lb. moisture blown per ton iron.

*Heat in Blast per Ton Iron per 1° F.*

$$9,692 \times 0.2375 \times 1 = 2,303 \text{ B.t.u. Heat in dry air.}$$

$$137 \times 0.48 \times 1 = 66 \text{ B.t.u. Heat in moisture.}$$

---


$$2,368 \text{ B.t.u. Total heat moisture and air.}$$

*Cubic Feet Gas per Ton Iron—Distribution—Heat.**Average Analysis Furnace Gas—Unwashed.*

$$\text{CO}_2 = 13.06 \times 0.1227 = 0.016025 \quad 19.70$$

$$\text{CO} = 25.78 \times 0.0781 = 0.020133 \quad 24.74$$

$$\text{H}_2 = 3.69 \times 0.00559 = 0.000206 \quad 0.25$$

$$\text{N}_2 = 57.47 \times 0.0783 = 0.044909 \quad 55.81$$

---


$$0.081363$$

$$0.1970 \times 311 = 0.05372 \text{ Weight C. in CO}_2 \text{ per pound furnace gas.}$$

$$0.2474 \times 37 = 0.10603 \text{ Weight C. in CO per pound furnace gas.}$$

---


$$0.15975 \text{ Weight C. per pound furnace gas.}$$

$$2,256 \text{ Coke per ton iron.}$$

$$15 \text{ Loss in flue dust.}$$

---


$$2,241 \times 0.8411 = 1,884.9 \text{ pounds C. charged in coke.}$$

$$1,117 \times 0.0975 = 198.9 \text{ pounds C. charged in limestone.}$$

---


$$1,993.8 \text{ pounds C. charged.}$$

$$86.4 \text{ pounds C. in iron.}$$

---


$$1,907.4 \text{ pounds C. in gas.}$$

$$1,907.4 \div 0.15975 = 11,940 \text{ pounds gas per ton iron.}$$

$$11,940 \div 0.081363 = 146,750 \text{ cu. ft. gas per ton iron at } 32^\circ \text{ F.}$$

$$146,750 \times \frac{521}{491} = 155,702 \text{ cu. ft. gas per ton iron at } 62^\circ \text{ F.}$$

$$156,000 \times 0.95 = 148,000 \text{ cu. ft. gas available per ton iron allowing for 0.5 per cent. leakage.}$$

$$148,000 \times 0.275 = 40,700 \text{ cu. ft. gas available at stoves per ton iron.}$$

$$148,000 \times 0.725 = 107,300 \text{ cu. ft. gas available at boilers per ton iron.}$$

$$40,700 \times \frac{443}{1440} = 12,520 \text{ cu. ft. gas available at stoves per minute.}$$

$$107,300 \times \frac{443}{1440} = 33,010 \text{ cu. ft. gas available at boilers.}$$

$$0.2474 \times 4,325 = 1,069.9$$

$$0.0025 \times 62,032 = 155.1$$

---


$$1,225.0 \text{ B.t.u. heat per pound furnace gas.}$$

$$1,225 \times 0.081363 \times \frac{491}{521} = 93.9 \text{ B.t.u. per cu. ft. gas at } 62^\circ \text{ F.}$$

# Comparative Working of Kennedy Two-Pass Hot-Blast Stoves. Clean and Dirty Gas.

Estimated Savings by Use of Clean Gas.

| DIRTY GAS.                                           |                                            | CLEAN GAS.                                           |                                            |
|------------------------------------------------------|--------------------------------------------|------------------------------------------------------|--------------------------------------------|
| <i>Heat in Blast.</i>                                |                                            | <i>Heat in Blast.</i>                                |                                            |
| Gas available in stoves per ton iron.....            | 40,700                                     | Gas available in stoves per ton iron.....            | 39,500                                     |
| Heat efficiency of stoves on dirty gas.....          | 55.86, or 56%                              | Heat efficiency of stoves on clean gas.....          | 63.98, or 64%                              |
| Heat available in gas per ton iron.....              | $40,700 \times 93.9 = 3,821,730$ B.t.u.    | Heat available in gas per ton iron.....              | $38,500 \times 93.9 = 3,709,050$ B.t.u.    |
| Heat available in blast per ton iron.....            | $3,821,730 \times 0.56 = 2,140,169$ B.t.u. | Heat available in blast per ton iron.....            | $3,709,050 \times 0.64 = 2,373,792$ B.t.u. |
| Heat in blast per 1° F.....                          | 2,368 B.t.u.                               | Heat in blast per 1° F.....                          | 2,968 B.t.u.                               |
| Average temperature cold blast (from all tests)..... | 207° F.                                    | Average temperature cold blast (from all tests)..... | 207° F.                                    |
| Rise in temperature of blast.....                    | $2,140,169 \div 2,368 = 908^\circ$ F.      | Rise in temperature of blast.....                    | $2,373,792 \div 2,968 = 1,008^\circ$ F.    |
| Average temperature hot blast.....                   | 908 and 207 = 1,110° F.                    | Average temperature hot blast.....                   | 1,008 and 207 = 1,210° F.                  |
| Gain in temperature of blast.....                    |                                            | Gain in temperature of blast.....                    | 1,210 — 1,110 = 100° F.                    |
| Gain in heat in blast.....                           |                                            | Gain in heat in blast.....                           | $2,373,792 - 2,140,169 = 233,623$          |
|                                                      |                                            | Net Saving per ton iron by higher heat.....          | $233,623 \times 2.77 = \$0.0019$           |
|                                                      |                                            |                                                      | $8.144 \times 2.240$                       |

NOTE.—Efficiency of stove is figured on latent heat only of gas, and is representative of stove efficiency after half the life of a run. Efficiencies obtained in clean and raw gas reflect all thermal relations of the sensible heats of burned and unburned gas in both cases.

*Loss in Heat to Blast while Stove is off for Cleaning.*

On dirty gas, a stove is taken off for cleaning every four months. The stove is off five days. The first day the stove is left on blast throughout the day in connection with the other three stoves, and is run down to about 600°. Another day is taken in cooling the stove down to 100° F. Two days are usually required for cleaning when the stove is not in bad shape. The fifth day, the stove is put on gas and brought back to about 1,250°.

NOTE.—These figures were based on separate stove tests taken independently and not necessarily those preceding these calculations.

At the Duquesne Furnaces we have never taken a stove off for cleaning during the campaign. At such times as we reline, say during four years' service, the entire set of stoves do not accumulate more than 10,000 lb. of dirt.

# *Kennedy Two-Pass Hot-Blast Stoves. Clean and Dirty Gas.*

## *Estimated Savings by Use of Clean Gas.*

| DIRTY GAS.                                                                                                                   |  | CLEAN GAS.                        |
|------------------------------------------------------------------------------------------------------------------------------|--|-----------------------------------|
| Heat taken out of brickwork by blast in cooling down to 600° $2,162,000 \times 0.26 \times (900 - 600) = 168,686,000$ B.t.u. |  | No cleaning necessary.            |
| a Heat necessary to bring stove back to 1,250° F. ....                                                                       |  |                                   |
| $2,162,000 \times 0.28 \times 1,110 = 623,953,000$ B.t.u.                                                                    |  |                                   |
| Net loss of heat in brickwork .....                                                                                          |  |                                   |
| $623,953,000 - 168,686,000 = 455,317,000$ B.t.u.                                                                             |  |                                   |
| a Net available heat in gas represented. ....                                                                                |  | Gain for clean gas. .... \$0.0182 |
| Tonnage during period of four months. ....                                                                                   |  |                                   |
| $455,317,000 \div 0.64 = 711,429,000$ B.t.u.                                                                                 |  |                                   |
| Heat lost per ton iron in gas. ....                                                                                          |  |                                   |
| $443 \times 30 \times 4 = 53,160$ tons.                                                                                      |  |                                   |
| $711,429,000 \div 53,160 = 13,383$ B.t.u.                                                                                    |  | Clean and Dirty Gas.              |
| Loss per ton iron by lost heat, one stove. ....                                                                              |  |                                   |
| $13,383 \times 0.64 \times 2.77 = 0.0038$                                                                                    |  |                                   |
| Loss per ton iron by lost heat. ....                                                                                         |  |                                   |
| $3,144 \times 2.240$                                                                                                         |  |                                   |
| a Efficiency and heat of a clean gas stove figured.                                                                          |  |                                   |
| $0.0038 \times 4 = \$0.0182$                                                                                                 |  |                                   |

## *Comparative Working of Kennedy Two-Pass Hot-Blast Stoves. Clean and Dirty Gas.*

### *Estimated Savings in Use of Cleaned Gas.*

**DIRTY GAS.**

*Loss in Heat in Blast while Stove is off Cleaning.—(Continued.)*

The stove being off for cleaning five days, during which time none of the heat in the stove is available. The loss in heat to the blast is considerable. Our records show a drop of from 100° to 150° during this period.

|                                                                                 |                                              |
|---------------------------------------------------------------------------------|----------------------------------------------|
| Gas available for stoves per min.....                                           | 12,520 cu. ft.                               |
| While stove is off for cleaning 1/9 of this gas is diverted to the boilers..... | 12,520 × 1/9 = 1,390 cu. ft. per M           |
| And the remainder is burned in the stoves.....                                  | 12,520 × 8/9 = 11,130 cu. ft. per M          |
| Heat usually available in gas.....                                              | 12,520 × 88.9 = 1,175,628 B.t.u.             |
| Heat available in gas while one is off for cleaning.....                        | 11,130 × 88.9 = 1,045,107 B.t.u.             |
| Loss in available heat in gas per minute.....                                   | 1,175,628 — 1,045,107 = 130,521 B.t.u.       |
| Loss in heat in blast per minute.....                                           | 130,521 × 0.56 = 73,092 B.t.u.               |
|                                                                                 | 73,092 × 1.440 = 100° F.                     |
| Loss in temperature blast.....                                                  | 2,368 × 418                                  |
| Loss in heat in blast for period stove off.....                                 | 73,090 × 1.440 × 5 = 526,248,000 B.t.u.      |
| Loss in heat for four stoves.....                                               | 526,248,000 × 4 = 2,104,992,000 B.t.u.       |
| Loss per ton iron.....                                                          | 39,580 × 2.77 = \$0.0156                     |
|                                                                                 | 3,144 × 2,240                                |
| Heat available for boilers.....                                                 | 1,390 × 88.9 × 1,440 × 4 = 75,180,096 B.t.u. |
| Boiler horse power available.....                                               | 75,180,096 ÷ 99,784 = 1,258 B.H.P.           |

**CLEAN GAS.**

No cleaning necessary.

Gain by use of clean gas..... \$0.0156



Comparative Working of Kennedy Two-Pass Hot-Blast Stoves. *Clean and Dirty Gas.*

## Estimated Savings by Use of Cleaned Gas.

| DIRTY GAS.                                                                                                                                                                                                                                                                                                                                    |                                                                          | CLEAN GAS.                     |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|--------------------------------|----------|
| Value B. H. P. ....                                                                                                                                                                                                                                                                                                                           | $1,258 \times 4 \times \$1.38 = \$3.10$                                  | Less boiler house credits..... | 0.0002   |
| Value B. H. P. for four stoves.....                                                                                                                                                                                                                                                                                                           | $\frac{2,240}{3}$                                                        | No cleaning necessary.         |          |
| Value B. H. P. per ton iron.....                                                                                                                                                                                                                                                                                                              | $3,100 \times 4 = 12.40$                                                 |                                |          |
|                                                                                                                                                                                                                                                                                                                                               | $12.40 \div 53,160 = 0.0002$                                             |                                |          |
| On account of deposition of dirt in the wall of the stove, we find it necessary to clean the well of each stove out once a day. During this time the cleaning door is wide open and there is a great inrush of air. From test made with large excess of air, it appears that the efficiency drops from 56 to 50 per cent. during this period. |                                                                          |                                |          |
| Four stoves off for cleaning one hour each = 4 hours per day.....                                                                                                                                                                                                                                                                             | $\frac{4 \times 60 \times 12,520}{3} =$ (gas burned) 1,001,600 cu. ft.   |                                |          |
| Heat available.....                                                                                                                                                                                                                                                                                                                           | $1,001,600 \times 93.9 = 94,050,240$ B.t.u.                              |                                |          |
| Heat available in blast.....                                                                                                                                                                                                                                                                                                                  | $94,050,240 \times 0.56 = 52,668,134$ B.t.u.                             |                                |          |
| Heat available in blast when off cleaning.....                                                                                                                                                                                                                                                                                                | $94,050,240 \times 0.50 = 47,025,120$ B.t.u.                             |                                |          |
| Net loss on heat.....                                                                                                                                                                                                                                                                                                                         | $52,668,134 - 47,025,120 = 5,643,014$ B.t.u.                             |                                |          |
| Net loss per ton.....                                                                                                                                                                                                                                                                                                                         | $\frac{5,643,014 \times 2.77}{3,144 \times 2,240 \times 443} = \$0.0050$ | Gains for clean gas.....       | \$0.0050 |
| Cost labor on cleaning stoves.....                                                                                                                                                                                                                                                                                                            | 1 foreman at \$2.28 = 2.28<br>3 laborers at 1.35 = 5.55                  |                                |          |
| Total.....                                                                                                                                                                                                                                                                                                                                    | \$7.83                                                                   |                                |          |

Comparative Working of Kennedy Two-Pass Hot-Blast Stove. *Clean and Dirty Gas.*

## Estimated Savings by Use of Cleaned Gas.

| DIRTY GAS.                            |                           | CLEAN GAS.                                                   |          |
|---------------------------------------|---------------------------|--------------------------------------------------------------|----------|
| Cost of labor saved on clean gas..... | $7.83 \div 2 = \$3.195$   | Total Savings in Operating Furnace with Clean Gas at Stoves. |          |
| Saving per ton.....                   | $3.195 \div 443 = 0.0068$ | On increased heat.....                                       | \$0.0919 |
|                                       |                           | On cleaning stoves.....                                      | 0.0288   |
|                                       |                           | On cleaning well.....                                        | 0.0050   |
|                                       |                           | On cleaning labor.....                                       | 0.0068   |
|                                       |                           | Total.....                                                   | 0.1345   |
|                                       |                           | Less boiler credits.....                                     | 0.0002   |
|                                       |                           | Saving per ton.....                                          | 0.1343   |
|                                       |                           | Less cost of cleaning gas (at average cost '12).....         | 0.0345   |
|                                       |                           | Net saving on stoves.....                                    | \$0.0998 |

*B.t.u. Saved by Use of Cleaning Gas, per Ton.*

|                     | B.t.u.  |
|---------------------|---------|
| Higher heat.....    | 233,623 |
| Cleaning stove..... | 35,318  |
| Cleaning well.....  | 12,738  |
| Total.....          | 281,679 |

$$281,679 \div 3144 = 85 \text{ lb. coke.}$$

$$85 \times 0.0606 = 5.2 \text{ silica.}$$

$$5.2 \times 1.4 = 7.3 \text{ lime.}$$

$$7.3 \div 0.469 = 15.6 \text{ lb. limestone.}$$

*Cost of Limestone.*

$$\frac{15.6 \times 1.03}{2,240} = \$0.0072$$

*Increased Production.*

$$\begin{aligned} 2,256 \times 60.82 \times 443 &= 60,783,995 \text{ cu. ft.} \\ 2,171 \times 60.82 &= 132,101 \text{ cu. ft.} \\ 60,783,995 \div 132,101 &= 460 \text{ tons.} \\ 460 \div 443 &= 1.0384 - 3.84 \text{ increased yield.} \\ 1.356 \times 0.0384 &= \$0.0321 \text{ savings by increased production} \\ &\quad \text{on cost above.} \end{aligned}$$

*Gas Lost at Boilers.*

$$\begin{aligned} 85 \times 0.8411 &= 71 \text{ C. lost to gas.} \\ 71 \div 1,907 &= 3.72 \text{ decrease in amount gas made} \\ &\quad \text{on clean gas.} \\ 148,000 \times 0.9628 &= 142,500 \text{ cu. ft. gas available per ton Fe.} \\ &\quad \text{Fce. on clean gas.} \\ 142,500 - 39,500 &= 103,000 \text{ cu. ft. gas available per ton Fe at} \\ &\quad \text{boilers.} \\ 107,300 - 103,000 &= 4,300 \text{ cu. ft. gas lost to boilers per ton} \\ &\quad \text{iron.} \end{aligned}$$

*Summary.*

|                                     |          |
|-------------------------------------|----------|
| On better work on stoves.....       | \$0.0998 |
| Saving in limestone.....            | 0.0072   |
| Saving on increased production..... | 0.0521   |
| TOTAL SAVING PER TON IRON.....      | \$0.1591 |

It is shown in the foregoing paragraphs that a considerable saving is affected through washing gas for stoves, *i. e.*, \$0.1591, due principally to increased efficiency, capacity of heating available, and labor. The calculated figure of 130° difference in hot blast checks with the average temperature of our hot blast during the first eight months of this year. Nos. 1 and 2 Furnaces are on dirty gas and Nos. 3 and 4 on clean gas. All these stoves are practically the same, and the actual difference in temperature over this period is 129° in favor of

the clean-gas stoves. The boiler savings, which time prevents going into, will by similar deductions amount to a net saving of \$0.0348, due to less cleaning and greater efficiency. The difference in boiler efficiency is 6 per cent.

Gas cleaning brings up a number of very interesting developments and each one requires a careful study. We have only touched on the most important ones from the standpoint of the actual operation. Our tests have been carried out with extreme accuracy and represent average conditions. Installation of gas cleaning, like most other improvements, depends on local conditions and is just another problem to be solved. It is hoped that the data submitted may be of some assistance to the engineer who is wrestling with the subject.

I might say that, in our boiler practice, we gain an increased efficiency of about 8 per cent., but there is not the saving in the boilers that there is in the stoves. It is, in fact, doubtful whether a saving is made in the boilers, but we do think we make some saving. At all events, it is a far nicer plant to handle.

FREDERICK H. WAGNER,\* Baltimore, Md. (communication to the Secretary†):—The paper presented by Mr. Forbes deals with the subject of Blast-Furnace Gas Cleaning in a very comprehensive manner, and depicts the various apparatus used for this purpose; but I regret that no data on the relative cost of cleaning this gas at the various plants have been given, especially as in this country the same practice is almost universal, viz.: the use of (a) dry dust cleaners, (b) static washers, and (c) Theisen washers.

As the various plants are of practically the same design, using apparatus of the same character but with some structural modifications, it might be assumed that the costs of cleaning the gas would necessarily approximate each other in all instances; but this is not the case, and differences amounting to from one and a half to four times the minimum cost of 14 c. per 100,000 cu. ft. can be pointed out.

These differences are due to the variation in water used in the same character of apparatus, as well as to the difference in power consumed, and in some instances the cost of labor is in excess of what it should be, due to the location and design of the apparatus.

You are all familiar with these conditions, and it would be useless to waste your time by adding to the above statement, my present object being to call to your attention two systems which are being employed in Europe at present, and to point out the differences

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\* Non-member.

† Received Oct. 16, 1913.

between the two, as well as some discrepancies which have been published regarding one of them. I refer to the Feld plant at Pompey, France, and the Schwarz-Bayer plant at Donawitz, Germany.

Both the Feld and the Schwarz-Bayer washers, or disintegrators, have been described in Mr. Forbes's paper, but I desire first to call attention to the structural differences in these two machines, and which differences lead to an excess in power consumption in one machine over the other. You will note that in the Schwarz washer the water is disintegrated by the action of the horizontal rods attached to the disks revolving in opposite directions, and the paddle wheel on a boat is an exaggerated example of the action of these disintegrating rods; due to the resistance of the water to the blades of the paddle wheel, the boat is propelled, and the power consumed is in proportion to this resistance. If the disintegrating rods were made infinitesimally small there would be practically no resistance, and no power consumption, but then the water would not be disintegrated, or pulverized.

This also holds good for the new Theisen washer, which also employs these atomizing rods. The confined action of these machines, and the incompressibility of the injected water, also add to the power consumed, this action causing a loss in gas pressure during the passage of the gas through the washer, this loss in pressure being dependent upon the quantity of water injected. If gas is to be delivered at a certain fixed pressure, and a considerable portion of the original pressure is dissipated in passing through the apparatus, this loss must be made good by means of a fan, an additional power requirement over that which would be normal without the above pressure loss.

In the Feld washer the action is entirely different, and its design has been based upon the result to be achieved while pursuing the path of least resistance. The rapid revolution of the vertical shaft (100 rev. per minute for the largest size) causes a film of water to mount the inner surface of the cones and to leave them through the perforations at the top in a finely pulverized or atomized state, the only resistance therefore being that offered by lifting the weight of the water up the cone, plus the friction in the single, specially designed roller bearing at the top, from which the entire weight is suspended; the maximum back pressure thrown by this washer is only 2 in. of water.

As a power-consuming machine the Feld washer is therefore of a superior design, because the moving parts of the Feld washer offer less resistance to the prime mover, and the effort to pulverize the

water is minimized; as an example it may be mentioned that a Feld washer of a capacity to cool and primarily wash from 32,000 to 35,000 cu. ft. of gas per minute only requires 20 h.p. for its operation as against 115 h.p. for a standard Thiesen. I am unable to give the power for the Schwarz washer alone, as my data are for the total power used, including the fan, as explained below.

As a thermal machine some apparatus are superior to others, and the one which can bring the gas into the most intimate contact with fine sprays of water will reduce the total temperature, by condensing the water vapor carried in the gas, in the most efficient manner, and without any waste.

As explained by Mr. Forbes, the Feld primary washer is a combined washer and condenser, the lower portion being the active dust extractor and the upper portion the condenser, the hot water from the latter being the best dust remover; there the Feld washer, as a primary cleaner, can take the gas at any top temperature, the number of cooling chambers being arranged accordingly. It is a well-known fact that to properly remove dust from gas the entire dust particle must be thoroughly wetted, and as it ascends and meets the heavier water particles, it becomes weighted and falls to the bottom; this is the action in the Feld washer, where the gas enters at the bottom and leaves at the top, the water taking the counter direction.

The water vapor in the gas requires a certain amount of cold water for its condensation, and in spite of some statements made regarding the low water consumption of certain apparatus, it is a physical impossibility that this water vapor will be condensed with less cooling water than the thermal conditions require, and this theoretical figure will even be slightly exceeded in practice; the following case is given as an example of the theoretical quantity of water required for condensing or cooling purposes.

It is desired to reduce the temperature of the gas from 500° F. to 86° F., or from 260° C. to 30° C., the dew point of the gas being at 52° C. with 120 g. of water vapor content per cubic meter (46.5 grains per cubic foot). The heat value at 52° C. is 95.5 calories per cubic meter, and the heat capacity of the water-saturated gas at 52° C. amounts to 0.389 calorie per cubic meter.

At 260° C. the heat value will therefore be  $95.5 + 0.389 (260 - 52) = 176.5$  calories, or, a gas having a dew point of 52° C., due to its water content of 120 g. per cubic meter, and which gas is superheated to 260° C., possesses a total heat value of 176.5 calories referred to water content.

When the gas is brought into contact with the water in a Feld

washer it passes from a superheated into a saturated condition; the heat required for superheating is transformed into latent heat by the evaporation of water, and the total heat of 176.5 calories per cubic meter in a saturated condition corresponds to a temperature of about 63° C.; or upon entering the washer, the superheated gas is brought into such intimate contact with the water that the temperature is reduced from 260° C. to 63° C., during which period the gas passes into a water-saturated condition.

The amount of cooling water required to reduce the temperature of the gas from 260° C. to 30° C. is determined from the total heat in the gas; as seen above, the total heat in the gas at 260° C. amounts to 176.5 calories per cubic meter, and at 30° C. the total heat in the cooled gas is 31.12 calories per cubic meter, and this difference of  $176.5 - 31.12 = 145.38$  calories must therefore be absorbed.

Assuming that the cooling water has a temperature of 20° C. (68° F.), and that the water is heated in the cooling chambers of the washer to 55° C. (131° F.), 1 liter of water would absorb  $55 - 20 = 35$  calories, and for 145.38 calories there would be required  $\frac{145.38}{35}$

$= 4.15$  liters per cubic meter of gas, or in the case of a blast furnace producing 2,700,000 cu. ft. of gas per hour (76,500 cu. m.), the amount of water used would be  $76,500 \times 4.15 = 317,475$  liters per hour, or 31 gal. per 1,000 cu. ft. No additional water is required for washing the gas for stove or boiler use, as the hot water from the upper chambers is used for this purpose.

A statement has been published to the effect that the Schwarz-Bayer system at Donawitz used only 0.56 to 0.75 liter of water per cubic meter of gas, a physical impossibility if the gas contained any water vapor, and it is hard to imagine any condition in which this would not be true. The statement made no mention of water vapor content, but as the Feld plant at Pompey is of practically the same capacity as the Schwarz-Bayer at Donawitz, it is interesting to note the following comparison:

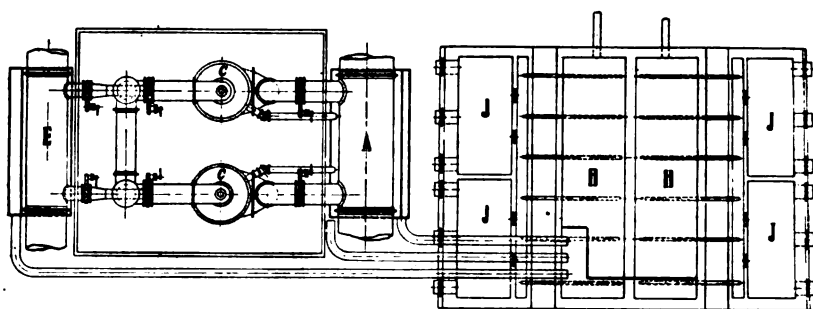
| Item.                           | Donawitz.          | Pompey.            |
|---------------------------------|--------------------|--------------------|
| Gas per hour.....               | 45,000 cu. m.      | 41,700 cu. m.      |
| Gas inlet temperature.....      | 130° to 200° C.    | 150° C.            |
| Gas outlet temperature.....     | 39° to 42° C.      | 25° C.             |
| Temperature difference.....     | 91° to 158° C.     | 125° C.            |
| Water in raw gas.....           | .....              | 120 gr. per cu. m. |
| Water in cleaned gas.....       | .....              | 2.8 gr. per cu. m. |
| Water used per cubic meter..... | 0.56 to 0.75 liter | 3.62 liters.       |
| Power consumed.....             | 124 to 128 h.p.    | 55 to 60 h.p.      |

This shows that only about one-sixth of the water used at Pompey was claimed at Donawitz. In passing upon this statement, the Editor of *Stahl und Eisen*, April 17, 1913, remarks that the low power consumption at Donawitz was probably due to the low dust content in the raw gas (1.8 to 2 g. per cubic meter), and therefore states that to his knowledge in other works where the dust content was higher, the power consumption was also higher. The dust content at the Pompey works, where the Feld washer is used, is from 3 to 5 g. per cubic meter, and the lower power consumption at Pompey arises from the greater mechanical efficiency of the Feld washer as compared with disintegrators of the Schwarz or later Theisen type. Besides this, the statement from Donawitz does not separate the power required for washer and fan, but assuming that the same fan power was consumed in both plants, viz., 35 h.p., the Feld power would have used 20 to 25 h.p. as against 89 to 93 h.p. for the Schwarz-Bayer.

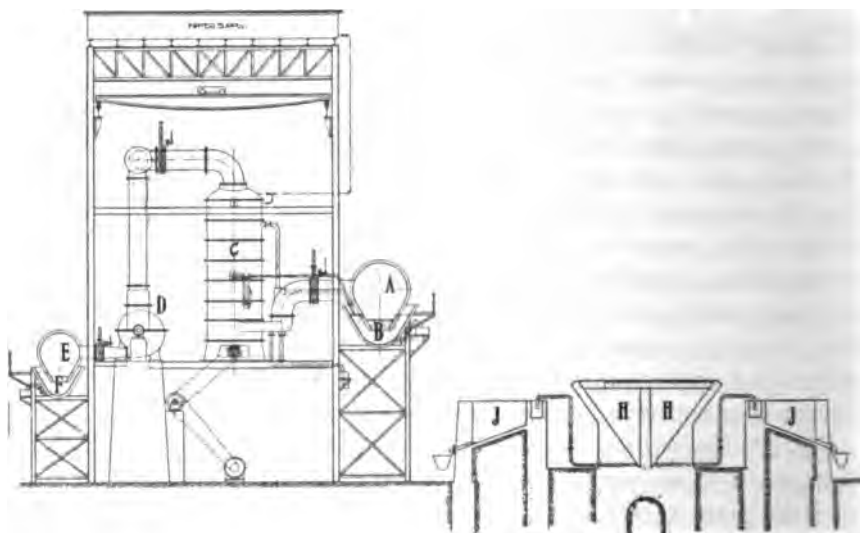
Referring again to the small amount of cooling water used at Donawitz, it must be assumed that a considerable amount of this injection water was vaporized, thus increasing instead of decreasing the water burden in the gas, and that to properly condense this vapor more water must necessarily be injected; this necessarily larger amount of cooling water requires a correspondingly higher power consumption, and only after the gas has been cooled below the dew point will it be possible to clean the gas with this small quantity of water. This is proved at Pompey, where three-quarters of the cooling water is drawn off from the Feld washer at the bottom of the cooling chambers (this water can be sent to a reservoir, cooled, and used over again) and only one-fourth of the 3.62 liters, or 0.9 liter, is used to clean the gas. The entire object of the cooler is to extract the water vapor from the gas, and not to increase its water content as must have been the case at Donawitz.

Fig. 27 shows the general arrangement of a Feld primary washing plant, and follows very closely the plant now being operated at Pompey; the plant shown in the diagram consists of

- A, Inlet main from dry dust catcher.
- B, Hydraulic dip for main.
- C, Feld washer.
- D, Exhauster or fan.
- E, Outlet main.
- F, Hydraulic dip for main.
- H, Settling tanks.
- J, Mud draw-off tanks.



GENERAL PLAN.



VERTICAL SECTION.

FIG. 27.—BLAST-FURNACE GAS-WASHING PLANT, FELD SYSTEM.



The method of operation is as follows: The gas from the dry dust catcher is conducted through main *A* to the bottom of the washers; this main is open at the bottom, the lower edges dipping into the hydraulic seal at *B*. Any dust deposited by friction in this main is dropped into the water and thus carried to the settling basins; the hydraulic head causing the heavier liquid to syphon out of *B* into the mud trough. This hydraulic feature also provides a safety valve against any possible explosion in the furnace, as an explosion can only blow the water seal and thus find relief. The gas passes upward through the Feld washer *C*, being cleaned in the lower sections and cooled in the upper sections. The exhaustor, or fan, *D*, moves the primarily cleaned gas on through the main *E*, from whence it is conducted to the stoves and boilers. If a final treatment of the gas for engine purposes is desired, an additional washer is placed behind main *E*, and a proportionate part of the gas sent through it, the primary washer taking the place of the usual towers, Zschocke, Steinhardt, Duquesne, etc., and the final washer replacing the usual Theisen. The mud-bearing water is conducted by means of open troughs to the settling basin *H*, where the mud is allowed to settle to the bottom, the clear water being drawn off at the top and used again. The hydraulic pressure of the water column in the basin forces the concentrated mud from the bottom of the tank up through the goosenecks which deposit the mud in the draw-off tank *J*, and finally by gates into cars or other means of conveyance for final deposit.

Fig. 27 shows the washers elevated and in a semi-inclosed building, a water-supply tank forming the roof, this construction at Pompey being due to local conditions. It is not necessary to house the apparatus, only a covering for the motors being required. The plant shown in Fig. 28 is designed to treat the gases from two blast furnaces, or 5,400,000 cu. ft. of gas per hour, and is intended to give this entire amount of final cleaning for engine purposes, hence the two final washers.

The arrangement of the plant permits of easy supervision and provides a continuous operating system, as no periodical shutdown periods for cleaning are required; one plant has been in continuous operation for 36 months without any shutdown for repairs or cleaning, operating 24 hr. per day.

The estimated cost of cleaning 5,400,000 cu. ft. of blast-furnace gas per hour for gas-engine purposes, with water at \$10 per million gallons and power at 1 c. per kilowatt-hour, less labor, would be about 6 c. per 100,000 cu. ft.; the labor is a minimum, as the only attention

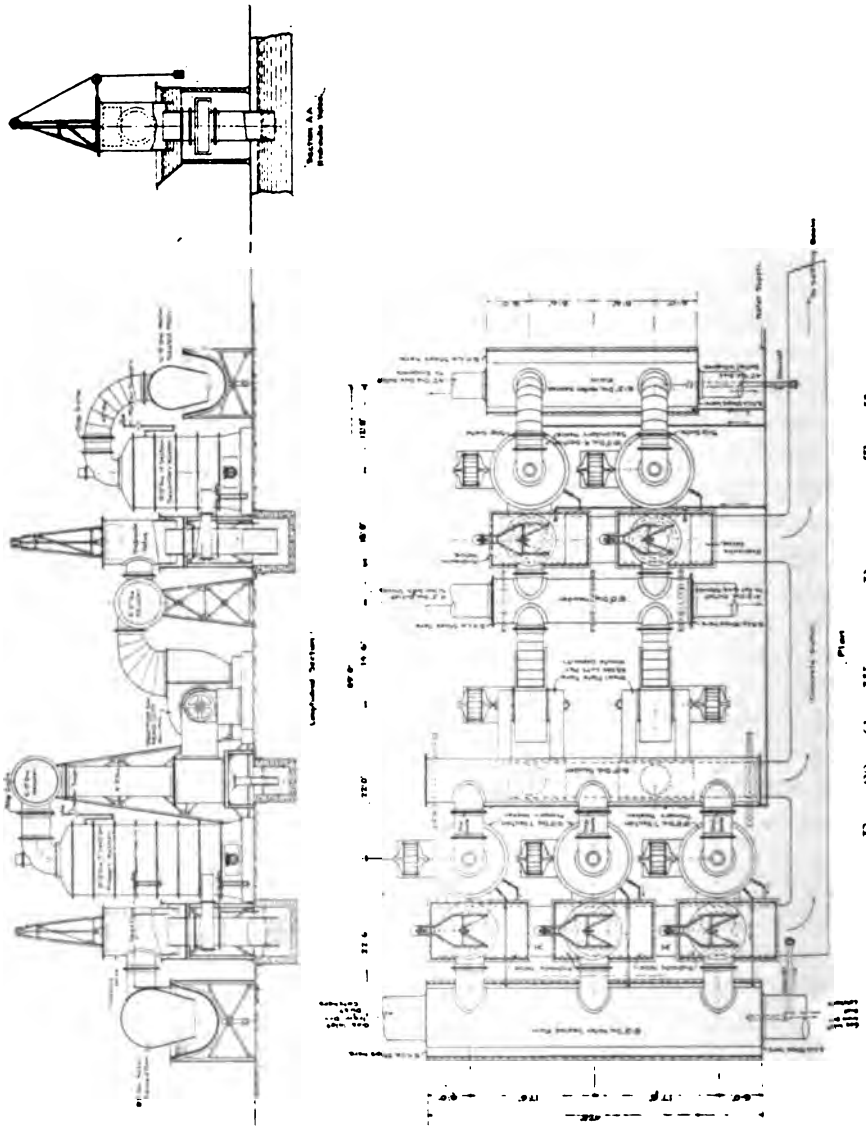


FIG. 28. GAS-WASHING PLANT FOR TWO FURNACES.

the apparatus requires is proper lubrication, all dust being carried away by water.

This entire plant, Fig. 28, consisting of three primary and two secondary or final washers, motors, fans, hydraulic valves, and pipe connections as indicated, capable of completely cleaning 5,400,000 cu. ft. of gas per hour, would cost about \$100,000, or about \$92,000 without hydraulic mains, using closed pipe, erected upon purchasers' foundations, and the ground space occupied is only 100 by 47 ft. as compared with a Schwarz-Bayer plant of the same capacity at 147 by 55 ft.

I would also state that Feld washers on dust extraction having a total capacity of 355,400,000 cu. ft. of gas per day are now in operation in Europe, with the result that the final cleaning of the gas leaves only 0.008 grain of dust per cubic foot, so that this system can no longer be considered as an experiment; in this connection I would refer to the statement made by B. W. Head<sup>1</sup> before the West of Scotland Iron and Steel Institute. Mr. Head had visited the European continent for the purpose of examining blast-furnace conditions; upon his return he called attention to the failure of the Scottish steel manufacturer to take advantage of the improved methods adopted in Germany, Belgium, and France, and was particular to lay stress upon the subject of gas washing for engine purposes, pointing out the difference in the methods practiced in the British Isles and those used on the Continent, mentioning especially the Feld vertical, centrifugal washer for this purpose.

The Feld washer embodies the following six principles in one machine, and which principles are universally acknowledged as necessary to completely separate dust from a gas:

1. *Cooling*.—The hot gas upon entering the washer is intimately mixed with sufficient water to lower the temperature to the desired point, thus altering its volume, density, and vapor tension, producing a dew point which precipitates the moisture held in suspension.

2. *Impinging*.—The gas, upon entering the washer, impinges upon the water spray, which in turn throws it upon the sides of the washer, from whence it impinges upon the bottom plate of the next chamber.

3. *Centrifugal Action*.—The gas is subjected to centrifugal action in that when it comes in contact with the water thrown out by the revolving cones it is whirled about in each washing chamber, because the water leaves the cones on a tangent and carries the gas with it; this centrifugal action can best be estimated when it is stated that

<sup>1</sup> *Journal of West of Scotland Iron and Steel Institute*, vol. xix, Nos. 6 and 7, pp. 286 and 319.

the periphery speed of the cones delivering the water is 1,580 ft. per minute.

4. *Direction.*—The direction, or flow of the gas, is constantly changed, in that the whirling water carries the gas with it in a circular direction, after which it passes upward, and then at right angles to the upward flow across the partition plate, and then up through the ports to have this cycle repeated in the next chamber.

5. *Velocity.*—The velocity is changed as many times as there are sections to the washer, the gas being contracted at the ports and expanded in the chambers; in a 10-ft. diameter washer the speed of the gas through the ports is at the rate of 42 ft. per second, and in the washing chamber at the rate of 9 ft. per second.

6. *Filtering and Washing.*—The gas is passed through a most minute spray of water, the water thus acting as a filter. No better washing effect can be produced than is that due to the water delivered by the cones; the water is so finely divided that it entirely surrounds and wets the dust particles, weighing them and causing them to drop. I regret that there are no Feld plants on dust extraction to be shown you in this country, our only washers here being used in various chemical processes.

Experiments were conducted at our shops by the representative of a large Western copper smelter with the object of determining the value of a Feld washer on the throwing down of sulphur fumes: these experiments proved so successful that the concern immediately ordered a washer to be placed in its experimental plant in California.

Before closing my remarks on wet cleaning, I would also refer to the Reco centrifugal washer, mentioned by Mr. Forbes. This washer is built with an idea of accomplishing the Feld results, but its very structural nature tends to remove any such successful issue. The washing water is thrown out into space in a thin stream from the horizontal shelves attached to the inverted cup; if these shelves are not perfectly horizontal more water will be thrown off at one point than at another, with the result that the gas will follow the line of least resistance and pass through the space but slightly filled with water, and thus escape the desired cleaning.

I also note that Mr. Forbes refers to the Halberger-Beth gas-cleaning system, which system is dependent upon bag filtration for its final cleaning of the gas. I regret to see that an attempt is being made to introduce this necessary evil adjunct of the copper, lead, and zinc smelter into blast-furnace practice; this evil in the smelter is deep rooted, the first bag house having been erected in this country in Colorado in 1887 and was used on lead fumes. It seems that the

whole tendency since that time has been to try to improve this evil instead of discarding it for something better, as is being done in Europe. This evil is most pronounced in lead smelters, where the operators are subject to continuous contact with lead dust, with consequent ill effect on health. A wet system should surely lend itself to better sanitary conditions.

A bag house passing 165,000 cu. ft. of gas per minute, operating 4,000 bags, cost, including building, woolen bags, distributing flue, fans, motors, and shaking arrangement complete, \$34.40 per bag, and occupies a ground space of 19,593 sq. ft., while a Feld plant of the same capacity for smelter work, based on the above number of bags, would cost about \$22 per bag, and occupy about 6,000 sq. ft. of ground area; the efficiency of the above bag house was found to be from 84 to 90 per cent., while under the same conditions a Feld plant could be depended upon to give 95 to 97 per cent. efficiency, and at the same time present a far safer investment, as if the gases, for some unforeseen reason, are not cooled properly before entering the bag chamber, fires will result, with the possible destruction of the cleaning plant. In the bag house price quoted above, precoolers and, if applied to blast-furnace practice, final coolers, were not included.

JOSEPH HARTSHORNE, Pottstown, Pa.:—It is stated in the abstract of the discussion of Mr. Forbes's paper by Mr. Wagner, read by the Secretary, that the Schwarz-Bayer cleaning plant at Donawitz and the Feld cleaning plant at Pompey are described and compared and that "the amount of water used at Donawitz is questioned."

Since neither the figures nor the reason for the question were given in the abstract, comment cannot be made upon them. I wish, however, to state that from my knowledge of Donawitz and of its management, I can bear witness to the care and accuracy of their work. I think any figures given by them may be accepted as accurate.

I saw several of these Schwarz-Bayer cleaners at work in various places in Europe in 1912. In the absence of my notes, I cannot give the exact figures, but the general results were that, in a 60,000 cu. m. machine, the requirements per 1,000 cu. m. were: total power, from 2.5 to 2.8 h.p., and water, 1.2 to 1.5 liters. Such a machine would reduce the dust from 12 g. per cubic meter to 0.1 g. A secondary, or finishing, machine would further reduce it to 0.01 g.

STUART B. MARSHALL, Dunbar, Pa.:—I wish to speak about Mr. Diehl's remarks, as my experience with the blast furnace has been

practically along those lines, without the elaborate statistical data which he has reported so completely. My observation at one furnace where the gas was not cleaned, right beside another where the gas was cleaned, enabled me to watch its effect upon the heating of the stoves of the same design; and it was an absolutely positive fact, so far as my experience is concerned, that with the cleaner gas the heats in the stoves were better and the cost of cleaning less; the gas under the boilers easier to handle, the efficiency and economy of the boilers better, and results were along the lines of Mr. Diehl's discussion.

That is, my practical experience has been, as he puts it, except that I have not had the means, or taken the time, to get up such complete data as he has. I think it is extremely valuable corroboration because it brings out the experience where you have one operated one way and the other operated the other way side by side. In my mind there is no doubt about the increased value of clean gas; especially, as Mr. Forbes states, when you have the clean gas you can get more heat efficiency in the stove by having more checkers, permitting the use of smaller spaces, and that is an important feature.

I think the more we develop along that line we will lower some of our costs, as Mr. Forbes has stated in his most excellent paper.

JOSEPH W. RICHARDS, South Bethlehem, Pa.:—I would call attention to the fact that the sensible heat which is lost by cooling is an important amount of heat, and if the gases are put through the washer and cooled at 100° F. we lose a very large amount of heat, which should be saved if possible. The amount of water vapor which is ordinarily in the gas is not very detrimental to the use of the gas. It carries out some sensible heat, but I do not think the water vapor affects the combustion of the gas any more than any other inert ingredient of the gas would. I think it would be highly desirable if a method of cleaning gas could be invented other than by washing it and reducing its temperature to ordinary temperature. If the Cottrell process, for instance, could be adopted in an apparatus that could be kept hot, so that the sensible heat of the gas could be conserved, it might then clean the gas completely and save the sensible heat which is carried out of the furnace, which is such an important item to save. I do not regard washing the gas as absolutely necessary in order to remove the last trace of fine particles; they might be removed by other means and the sensible heat which the gas contains thus saved.

J. E. JOHNSON, JR., New York, N. Y.:—I have been considering

this matter long the same lines on which Professor Richards has just spoken.

If the burnt gas is discharged from the stoves or boilers at a temperature as low as or lower than that at which it comes from the furnace there is obviously no loss from the presence of water vapor; that is to say, if the gas from the furnace is at  $500^{\circ}$ , as it often is, and is discharged from the stoves at  $500^{\circ}$ , the water vapor plays no part except to cut down the maximum combustion temperature, and if the gas could be freed of dust and burned under these conditions we should undoubtedly get 10 per cent. or 15 per cent. more heat from it than we do by cooling it down to atmospheric temperature and so condensing out the water vapor.

I have just been asking if anything has been done with the Cottrell process. It seems to me that the electrostatic method of cleaning the gas while it is hot and preserving that initial heat is the one which has the most to recommend it if it can be carried out on a commercial scale and with a reasonable capital expenditure. This of course does not refer to gas for gas engines, which must be cooled in any event.

SAMUEL K. VARNES:—I purposely refrained from giving any reason for our poorer results with the clean gas, hoping some one else would bring up the point. Professor Richards has just given the reason that we decided accounted for our results. We found the loss of sensible heat to be the determining factor. The combustion temperatures were about  $135^{\circ}$  F. lower with clean gas and this lower temperature was directly shown in almost equal amount in the blast temperatures secured.

J. W. RICHARDS:—I can understand why a plumber, who is not a scientific man, will paint a radiator a light color, such as you see here by the window. That appliance is intended to radiate heat, and yet they paint it the worst color they can get for that purpose; it should be black. On the other hand, I cannot understand why you blast-furnace men paint your stoves the best color for radiating heat. You want to keep the blast as hot as possible coming from the stoves to the furnace, also in the cleaning apparatus you want to conserve the heat of the gas as much as possible, and yet you paint them all black. If I had charge of a blast furnace I should at least try experiments to see whether it is not possible to find some kind of a paint or whitewash to keep those things white and thus reduce the radiation losses.

DINGLER MACHINE SHOP Co. (*Maschinen-Fabrik Aktien-Gesellschaft*), Zweibrücken-Falz, Germany (communication to the Secretary\*) :— In connection with the description of Halberger-Beth dry-cleaning method for blast-furnace gas, given by W. A. Forbes at the October meeting of the Institute, we have the pleasure, in accordance with the request of the Secretary, of submitting the accompanying estimates of the cost of installation and operation for plants of different capacities employing this method.

The operating cost, as guaranteed by us, is from 15 to 20 pfennig per 1,000 cu. m. of gas cleaned. But the latter figure is reached only when the installation is extremely expensive, by reason of unfavorable local conditions.

We have assumed 10 per cent. per annum for amortization, and 5 per cent. for interest.

The cost of power has been taken at about 2.5 pfennig per horsepower per hour, which is rather high for Europe. In Appendix III, where the horsepower per hour is taken at 4.5 pfennig, the resultant cost of cleaning 1,000 cu. m. of gas becomes 28.8 pfennig. But this high figure has never been reached in practice. On the contrary, we have been able to reduce the consumption of power per 1,000 cu. m. of gas from 105 to about 70 h.p.

For the supervision, even of the largest plant named, one man is enough, with an assistant, perhaps, for the work of lubrication. The discharge of dust into cars is easily performed by one such assistant.

As to the cost of filter-bags, we have calculated upon 6 months as the life of these bags; but they have lasted in practice as long as 18 months—effecting a further reduction of operating-costs.

The dust separated by our dry-cleaning plant is used with great advantage to increase the coherence of briquettes, thus giving to works using the Halberger-Beth system a profitable disposition of this otherwise troublesome by-product.

There are other possible ways of utilizing this dust; as an ingredient increasing the strength of cement; as an insulating material; and as a material in the manufacture of glass. These numerous openings for the utilization of the filter-dust is a special advantage of this system, avoiding, as it does, the troublesome and costly arrangements required for the disposal of this material under the wet-cleaning methods.

The installation-costs, as stated in the following Appendixes, include the cost of erection; and the cost of our shipment given, in Appendix I, for a plant in France, includes also the import-duty.

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\* Received Oct. 21, 1913.



*Appendix I.*—Calculation of profit for a dry-gas-cleaning plant, on the Halberger-Beth system. Assumed capacity, about 66,000 cu. m. of blast-furnace gas, at 0° C. and 760 mm. barometer.

*A. Cost of Installation.*

|                                                                  | Francs. |
|------------------------------------------------------------------|---------|
| (1) One shipment, including reserve.....                         | 219,000 |
| (2) Large sheet-iron work .....                                  | 50,000  |
| (3) Iron construction of building : about 70 tons at 325 fr..... | 22,750  |
| (4) Foundations, masonry, and roofing.....                       | 3,500   |
| (5) Driving-motors and equipment.....                            | 15,000  |
| (6) Dust-conveyor, etc.....                                      | 2,500   |
| Total.....                                                       | 312,750 |

*B. Operating Costs.*

|                                                                                                                                                  | Francs. |
|--------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| (1) Amortization (10 per cent.) and interest (5 per cent.).....                                                                                  | 46,900  |
| (2) Power, 200 h.p. for 360 days at 3 centimes per h.p. per hour..                                                                               | 65,000  |
| (3) Pay of two attendants at 1,800 fr.....                                                                                                       | 3,600   |
| (4) Repairs, lighting, and oiling.....                                                                                                           | 3,000   |
| (5) Bag-removals.....                                                                                                                            | 4,230   |
| (6) Dust-transportation (average of 10 g. per cu. m. of gas = 0.66 ton per hour, or $0.66 \times 24 \times 360 = 5702.4$ per year at 1.25 fr.).. | 7,140   |
| (7) Water-consumption, 0.1 liter per. cu. m. gas = $6.6 \times 24 \times 360 \times 0.1$ .....                                                   | 570     |
| (8) Steam-consumption, 10 kg. per 1,000 cu. m. gas.....                                                                                          | 11,450  |
| Total operating cost per year.....                                                                                                               | 141,890 |

Quantity of gas per year, 570,400,000 cu. m. Hence, cost of cleaning 1,000 cu. m. gas, 24.8 centimes. Since the dust can be sold at 7 fr. per ton, or  $0.66 \times 24 \times 360 \times 7 = 40,000$  fr. per annum, the net operating cost will be 101,890 fr., or 17.8 centimes per 1,000 cu. m. gas.

*Appendix 2.*—Cost-calculation per 1,000 cu. m. gas on the Halberger-Beth system. Assumed capacity of 48,000 cu. m. gas per hour, at 0° C., and 760 mm. barometer.

*A. Cost of Installation.*

|                                                                   | Marks,  |
|-------------------------------------------------------------------|---------|
| (1) Shipment of the Co., including reserve and mountings.....     | 173,500 |
| (2) Iron-construction for building, 55 tons, at 270 M.....        | 14,850  |
| (3) Foundations, masonry, roofing, and glass.....                 | 2,800   |
| (4) Motors and equipment : 2 of 150, 2 of 15, and 2 of 8 h.p..... | 15,000  |
| Total.....                                                        | 207,750 |

*B. Operation Costs.*

|                                                                                                      | Marks. |
|------------------------------------------------------------------------------------------------------|--------|
| (1) Amortization (10) and interest (5 per cent.).....                                                | 31,200 |
| (2) Power, $\frac{148 \times 24 \times 360 \times 3}{100}$ .....                                     | 38,400 |
| (3) Pay of two laborers at 1,500 marks.....                                                          | 3,000  |
| (4) Maintenance, lighting, and oiling.....                                                           | 2,600  |
| (5) Bag-renewals .....                                                                               | 4,620  |
| (6) Dust-transportation.....                                                                         | 2,480  |
| (7) Water-consumption, 0.1 liter per cu. m. gas, = $4.3 \times 24 \times 360$<br>$\times 0.01$ ..... | 415    |
| Operating cost per year.....                                                                         | 82,715 |

Quantity of gas cleaned,  $48,000 \times 24 \times 360 = 414,720,000$  cu. m.  
 Cost of cleaning per 1,000 cu. m. gas, 19.9 pfennig. If the dust is  
 sold at 6 marks per ton, there will be a credit of  $2,480 \times 6 = 14,780$   
 marks, or  $\frac{14,780,000}{414,720} = 3.6$  pfennig, reducing the cost per 1,000 cu.  
 m. gas to 16.3 pfennig.

*Appendix III.*—Cost calculation per 1,000 cu. m. of blast-furnace  
 gas, by the Halberger-Beth system. Assumed capacity, 30,000 cu.  
 m. of gas per hour. Plant extensible to capacity of 90,000 cu. m.

*A. Cost of Installation.*

|                                                           | Marks.  |
|-----------------------------------------------------------|---------|
| (1) One shipment, including reserve and after-cooler..... | 134,500 |
| (2) Iron-construction for building, 40 tons at 270 M..... | 10,800  |
| (3) Foundations, masonry, roofing, and glass.....         | 3,000   |
| (4) Motors with electrical equipment.....                 | 14,000  |
| (5) Dust-conveyor and sundries.....                       | 2,000   |
|                                                           | 164,300 |

*B. Operating Costs.*

|                                                                                                              |        |
|--------------------------------------------------------------------------------------------------------------|--------|
| (1) Amortization (10) and interest (5) per cent. ....                                                        | 24,645 |
| (2) Power consumption, $\frac{105 \times 24 \times 360 \times 4.5}{100}$ .....                               | 40,800 |
| (3) Pay of two attendants, one on each shift, at 1,500 m.....                                                | 3,000  |
| (4) Maintenance, lighting, and oiling.....                                                                   | 1,800  |
| (5) Bag-renewals.....                                                                                        | 2,880  |
| (6) Dust-transportation, 6 g. per cu. m. gas = $0.18 \text{ kg.} \times 240 \times$<br>$360 \times 1$ .....  | 1,550  |
| (7) Water-consumption (maximum), 0.1 liter per cu. m. gas = $3 \times$<br>$24 \times 360 \times 0.076$ ..... | 198    |
| Operating costs per annum.....                                                                               | 74,873 |

Quantity of gas obtained per annum,  $30,000 \times 24 \times 360 =$   
 $259,000,000$  cu. m. Hence, cost per 1,000 cu. m. =  $\frac{7,487,300}{239,000} = 28.8$   
 pfennig. Considering that the dust can be sold at 6 marks per ton,  
 or  $0.18 \times 24 \times 360 \times 6 = 9,300$  marks per annum, this credit re-

duces the cost to 65,573 marks, or about 25 pfennig per 1,000 cu. m. of gas.

LOUIS SCHWARZ & Co., Dortmund, Germany (communication to the Secretary \*) :—As discussion of Mr. Forbes's paper on the Cleaning of Blast-Furnace Gas, we present herewith some data relative to the cost of installation and operation of the Schwarz-Bayer disintegrator.

The capital expenditure for a gas-cleaning plant capable of treating 5,500,000 cu. ft. of gas per hour is, in Germany, approximately \$36,000.

Experience in many plants has proved that the power requirements range from 6 to 9 h.p. per 100,000 cu. ft. of gas.

The water consumption in treating a gas having a dust content of 2.50 to 3.50 grains per cubic foot is approximately 122 gal. per 100,000 cu. ft. of gas, when the cooling water has a temperature of 15° C.

The dust contents of gas cleaned for stoves and boilers in such an apparatus will range from 0.04 to 0.1 grain of dust per cubic foot, and in further cleaning such gas for gas engines the dust contents will range from 0.004 to 0.008 grain per cubic foot.

The cost of operation is in the neighborhood of 6 to 7 c. per 100,000 cu. ft. of gas, and this includes all operating charges.

We feel that our system has many advantages over other existing systems, especially in the way of low power consumption and low water consumption. The Schwarz-Bayer system occupies comparatively little ground space compared to most other systems.

The capital expenditure for pumps and piping is very small on account of the small amount of water consumed and on account of only requiring a head of 6 to 8 ft. of water.

EDUARD THEISEN Co., Munich, Germany (communication to the Secretary †) :—As discussion of Mr. Forbes's paper on the Cleaning of Blast-Furnace Gas, we present some particulars of the operation of a Theisen disintegrator gas washer for cleaning the gas for stoves and boilers at a blast-furnace plant in the Luxemburg district:

Number of revolutions per minute, 626.8.

Capacity of plant, 1,750,000 cu. ft. of gas per hour.

Water consumed, 230 gal. per 100,000 cu. ft. of gas.

Gas suction before entering disintegrator, 2.7 in. of water.

Gas pressure after leaving the disintegrator, 5.6 in. of water.

Dust content of gases before entering disintegrator, 0.5 grain per cu. ft.

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\* Received Oct. 16, 1913.

† Received Oct. 16, 1913.

Dust content of gases after leaving disintegrator, 0.01 grain per cu. ft.

Power required, 11.5 to 12 h.p. per 100,000 cu. ft. of gas.

At the same plant the operating particulars obtained in cleaning gas for gas engines are as follows:

Number of revolutions per minute, 658.

Water consumed, 415 gal. per 100,000 cu. ft. of gas.

Pressure of gas before entering disintegrator, 3.5 in. of water.

Pressure of gas after leaving disintegrator, 6 in. of water.

Dust content of gas before entering disintegrator, 0.4 grain per cu. ft.

Dust content of gas after leaving disintegrator, 0.005 grain per cu. ft.

Power required, 16 h.p. per 100,000 cu. ft. of gas.

The present Theisen disintegrator is a great improvement over the former Theisen apparatus, particularly in the amount of power required, and this apparatus has been adopted on an extensive scale in European blast-furnace plants.

FOWLER & MEDLEY Co., Liverpool, England (communication to the Secretary \*):—As discussion of Mr. Forbes's paper on the Cleaning of Blast-Furnace Gas, we present herewith particulars taken from the results shown by our vertical gas-washing machines installed at the works of the Partington Steel & Iron Co., Ltd., Irlam, Manchester, England, and we have chosen these machines as examples because they are both the latest in design and the largest we have yet built.

This installation consists of five of our No. 8 cleaners, taking gas from three blast furnaces. At present two furnaces are in blast and three of our cleaners in use and the results of the tests made by the Partington Steel & Iron Co. are:

Gas passing per hour per machine, 500,000 cu. ft.

Dust in gas before cleaners, 176 grains per 100 cu. ft.

Dust in gas after cleaners, 0.88 grain per 100 cu. ft.

Power used to drive each machine, 11 kw. 14 B. h.p.

Pressure used in passing the gas through the cleaners,  $\frac{3}{8}$  in. of water gauge.

Water used in each cleaner, about 6,000 gal. per minute.

The water used in this plant is canal water, but we use sea water elsewhere, and also water that has been settled and cooled and returned to the cleaners.

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\* Received Oct. 16, 1913.

The ground space used is 10 by 10 ft. for each cleaner.

The foundation is a ring of concrete 6 ft. 6 in. in diameter and 2 ft. 6 in. high.

The cleaners themselves remain perfectly clean.

There is no visible deposit of dust in the stoves or the boiler flues.

### *Capital Outlay.*

The price of each No. 8 machine is \$3,250.

The outlay per machine erected and ready for use, with 20-h.p. vertical spindle, 600 rev. per minute motor, motor panel, wiring and foundations, but not including gas mains and water supply, would be about \$3,900. No buildings are needed.

### *Operating Cost No. 8 Cleaner per Year of 8,736 Hr.*

|                                                           |              |
|-----------------------------------------------------------|--------------|
| Power at 0.5 c. per kilowatt-hour.....                    | \$475        |
| Depreciation at 10 per cent. per annum.....               | 390          |
| Stores.....                                               | 10           |
| Attendants, 2 men for 12 machines at \$7.50 per week..... | 65           |
| Total operating cost exclusive of water supply.....       | <u>\$940</u> |

### *Advantages of the Fowler & Medley Gas Coolers and Cleaners.*

1. Low first cost.
2. Low operating expenses. Note how little power is needed.
3. Efficient cooling and cleaning.
4. The machines keep themselves perfectly clean, so that, however dirty the gas entering them may be, they do not have to be shut down periodically to be cleaned.
5. The pressure required to send the gas through the cleaners is low, so that no fan is necessary for feeding stoves and boilers with the clean gas.
6. The ground space needed is small.
7. The foundations needed are cheap.
8. No buildings are required.
9. We are now prepared to build machines of such a size that one only would be needed for each blast furnace. Such a machine would not require more power or water than the No. 8 size of which we have given particulars above, so far as its capacity for cleaning is concerned.
10. For fine cleaning of the gas for use in gas engines, after it has been washed and cooled in machines of the type exhibited, we make a cleaner of exactly the same general type, but with the spraying disks so fed with water that the requirements per machine do not exceed 150 gal. per hour.

With such secondary cleaning, troubles in gas engines due to dust entirely disappear.

W. A. FORBES:—I have not much to add to the very able discussions by the various gentlemen. I would like to make it plain, however, that the blast-furnace conditions under which Mr. Varnes now operates are altogether different from the conditions under which Mr. Diehl operates, especially in relation to the amount of water vapor in the issuing gas. The furnaces with which Mr. Varnes is connected use nodulized Cuban ore containing practically no moisture, and produce very little dust, while the furnaces which Mr. Diehl operates use fine Mesabi ore almost exclusively, containing 15 to 20 per cent. of moisture, and this ore, as is well known, produces large quantities of dust. In addition to the high natural moisture in the Mesabi ore, a certain amount of water is added to the stock before charging, to try to reduce the amount of dust blown over. Consequently, the gas under Mr. Diehl's conditions contains a great deal more water vapor than under Mr. Varnes's conditions, and it has been our experience that it is a distinct advantage to reduce the amount of water vapor in the gas by cooling. This reduction in amount of water vapor results in better combustion of the gas in the stoves and under the boilers, and much more than compensates for the loss of sensible heat in the gas incident to cooling. I might also add that Mr. Diehl's ore conditions prevail at a large majority of the American blast furnaces.

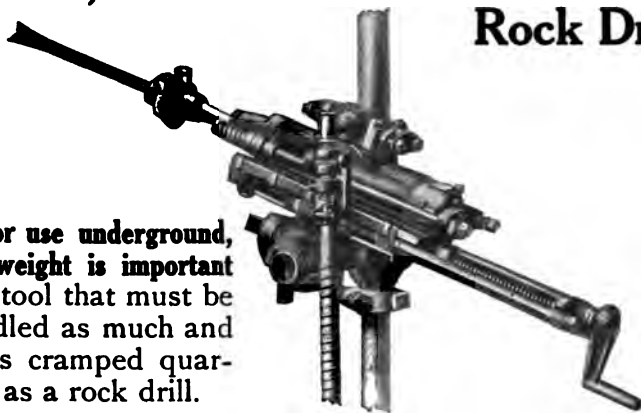
In regard to the written discussion by manufacturers of various foreign systems, it is unfortunate that only the Feld, of those participating in these discussions, has an American representative, as otherwise the criticisms of some of the systems by Mr. Wagner, the Feld representative in this country, could have been answered. I think it is only fair to state that the Feld system has not been adopted on the European Continent to nearly the extent of any of the other Continental systems referred to in the discussions, or in England to the extent of the English system described by me. Answering Mr. Wagner's remarks about the Halberger-Beth system, which is dependent upon bag filtration for cleaning the gas, I would draw the gentleman's attention to the many installations of this system which have been erected in Europe since it was first brought out less than five years ago. The numerous installations are largely due to the general belief that there is no other system which cleans blast-furnace gas so thoroughly as the Halberger-Beth.

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## No. 2, Sullivan "LITEWEIGHT" Rock Drills

For use underground, low weight is important in a tool that must be handled as much and in as cramped quarters as a rock drill.



## Sullivan "LITEWEIGHT" Drills

have been designed especially for underground service, for sinking, drifting, raising, for any work for which a piston drill is best suited.

Lighter, stronger, tougher metals have been used in building these drills, reducing their weight by from 35 to 70 pounds, as compared with older drills of equal cylinder diameter.

This has been done with an actual increase in the stability—resistance to wear and breakage—of the drills, and in their drilling speed and air power economy.

"LITEWEIGHT" Drills can be supplied with the Water Jet or Air Jet feature, mentioned last month, if exceptional cutting speed is an essential, or when trouble is found in cleaning the holes.

**THEY COST US MORE TO MAKE—THEY COST YOU LESS TO USE.**

*Bulletin No. 866-H.*

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## Rapid Shaft Sinking with the “JACKHAMER”

A Montana copper mine used two “Jackhamers” in sinking a vertical shaft 19' 6" x 6' 10" in the clear, from the 1200 foot level to the 1800 foot level.

The average round was:—eight cut holes, eight lifters, six back holes and six end holes, totaling 192 feet of drilling or 96 feet per drill.

The rock is a hard granite and the average time, day after day, is five hours for drilling the entire round.

From Jan. 20th to Feb. 15th, the shaft was sunk and timbered 110 feet—in spite of eleven shifts lost by an accident.

Piston drills were used before the “Jackhamers” were installed, and the best record made with the larger drills was 60 feet of shaft in one month.

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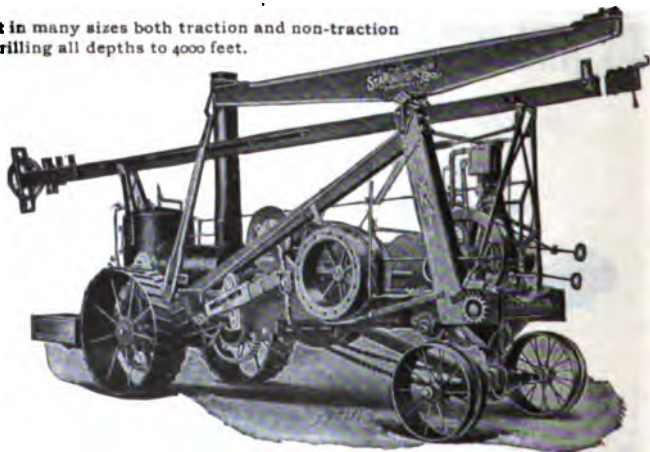
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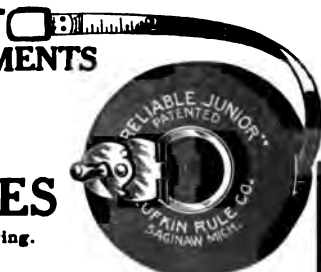
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### **PROPOSALS FOR MEMBERSHIP.**

A blank proposal for membership is included in each Year Book and Bulletin. In the event of not being able to secure such a one, applications for membership can be made out on any blank piece of paper, provided they include the class to which the candidate is proposed, whether member, associate or junior member; the signature of three members or associates (junior members must also have the endorsement of two of their instructors); a brief history of the candidate, including date and place of birth, his education and technical record, and finally a signed statement by the applicant that he desires to become a member.

# An Actual Record of the Service Rendered by Baldwin-Westinghouse Electric Mine Locomotives.



At the mines of the Ray Consolidated Copper Company, Ray, Arizona, there are eleven 10-ton Baldwin-Westinghouse Electric Mine Locomotives in operation. The following information is proof of the phenomenal record of low repair and maintenance cost made by these locomotives.

Standard Westinghouse bronze armature bearing with oil and waste lubrication as supplied on these locomotives.

## BRUSHES AND COMMUTATORS

The first shipment of locomotives was put into operation May, 1911, and additions have been made from time to time until now a total of 11 locomotives are in use. In this time not a single brush has been changed, nor a single commutator turned down.

## BEARINGS

In the spring of the present year, one of the motors was removed from the first locomotive installed to ascertain the general condition and amount of wear in the bearings. General condition of the motor was A-1. The armature, commutator, and brushes were in perfect shape. A careful test of the armature bearings showed that in practically two years of operation the wear was only .003%.

## CONTROLLERS AND RESISTORS

A careful system of inspection is carried out at Ray, and when it is found that contact fingers become badly worn or burred,

The above statement emphasizes the reliability of Baldwin-Westinghouse Mine Locomotives. The new cast steel bar frame design has many features far superior to the earlier types, used by the Ray Company. Full information about these locomotives can be obtained by addressing either Company

they are either smoothed up or replaced. Up to date not a single segment has been replaced on any of the controllers.

No trouble has been experienced with the grid resistors; only three grids having been replaced in three years time, and this was due solely to a collision, in which the grid was damaged.

## MECHANICAL PARTS

The foregoing does not cover repairs to wearing parts, such as brake shoes, trolley poles, etc., which of necessity must be replaced from time to time. With regard to wheels, however, only one pair of wheels has been changed in two years.

Two of these locomotives are used for general purposes, such as hauling mine timbers, etc. The remainder are used for hauling ore. The output of the mine is 6000 tons in 16 hours, at the present time. The average train consists of 30 to 35 cars holding 5 tons of ore each, and weighing approximately 2 tons each.

THE BALDWIN LOCOMOTIVE WORKS

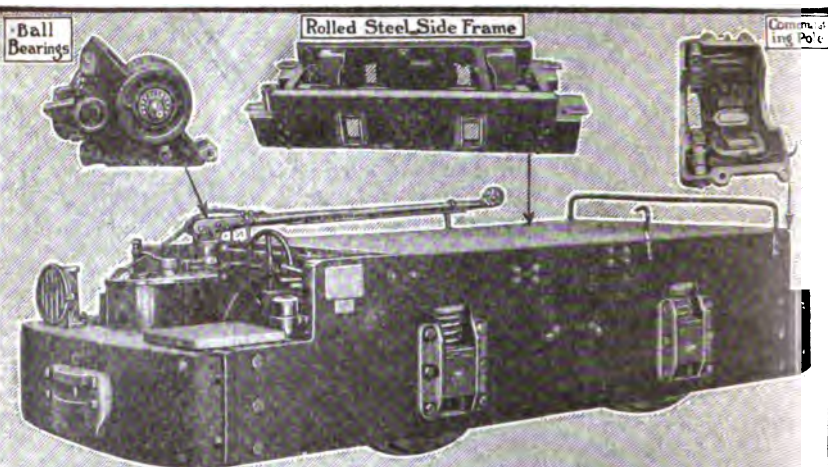
Philadelphia, Penna.

WESTINGHOUSE ELECTRIC & MFG. CO.

East Pittsburgh, Penna.



One of the locomotives at the mines of the Ray Company.



## Get ALL good features in ONE Locomotive

Mine service demands **rolled steel side frames** and **commutating pole ball bearing** motors. The G-E mining locomotive has these features, whose success has been assured, and every other essential requisite necessary to meet mine haulage conditions.

The rolled steel side frames give great strength. The commutating poles insure perfect commutation and lengthen brush wear.

### Ball Bearings Banish Repairs

The ball bearings used for G-E mining locomotive motors prevent armature from touching pole pieces, keep oil out of motor, maintain commutator in alignment, cut down bearing friction and reduce quantity of lubricant required.

Our mining locomotive specialists are ready to give you all desirable features in one G-E mining locomotive.

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